AGREEMENT NO. CE 80/2017 (SP)

DEVELOPMENT OF A COMMON SPATIAL DATA INFRASTRUCTURE- BUILT ENVIRONMENT APPLICATION PLATFORM

FEASIBILITY STUDY

FINAL REPORT

規劃署
Planning Department

ARUP

Planning Department

Agreement No. CE 80/2017 (SP)

Development of a Common Spatial Data Infrastructure - Built Environment Application Platform – Feasibility Study

Final Report

REP-006-03

Final | 10 March 2020

Ove Arup & Partners Hong Kong Ltd
Level 5 Festival Walk
80 Tat Chee Avenue
Kowloon Tong
Kowloon
Hong Kong
www.arup.com

Job number 260573

ARUP

Contents

Abbreviations and Acronyms

AFCD	Agriculture, Fisheries and Conservation Department
AI	Artificial Intelligence
AM/FM	Automated Mapping / Facilities Management
API	Application Programming Interface
AR	Augmented Reality
ArchSD	Architectural Services Department
AURIN	Australian Urban Research Infrastructure Network
AVA	Air Ventilation Assessment
BEA	Built Environment Applications
BEAP	Built Environment Application Platform
BEAWG	Built Environment Application Working Group
BD	Buildings Department
B/Ds	Bureaux/Departments
BIM	Building Information Modelling
BLM	Building Lifecycle Management
B(P)R	Building (Planning) Regulations
BRAVO	Building Records Access and Viewing On-line
C&SD	Census and Statistics Department
CAD	Computer-Aided Design
CBD	Central Business District
CCTV	Closed Circuit Television
CEDD	Civil Engineering and Development Department
CFD	Computational Fluid Dynamics
CGIS	Corporate Geographic Information System
CNN	Convolution Neural Network
CoE	Centre of Excellence
CPDH	Core Planning Data hub
CPLD	Committee on Planning and Land Development
CPU	Central Processing Unit
CSDI	Common Spatial Data Infrastructure
CGSIP	Common Geospatial Information System Platform
CLP	China Light & Power
CSDSC	Common Spatial Data Steering Committee
DC	District Council
DEM	Digital Elevation Model
DEVB	Development Bureau
DEVIN	Development Intensity
DIA	Drainage Impact Assessment
DMS	Digital Mapping System
DMZ	De-Militarised Zone
DOP	Digital Orthophoto
DPO	District Planning Office
DSD	Drainage Services Department
DSM	Digital Surface Model
DTM	Digital Terrain Model
DTSWG	Data and Technical Standards Working Group
EDB	Education Bureau
EIA	Environmental Impact Assessment

EIAO	Environmental Impact Assessment Ordinance
EKEO	Energizing Kowloon East Office, Development Bureau
EMPC	Electronic Mark-Plant Circulation system
EMSD	Electrical and Mechanical Services Department
EPD	Environmental Protection Department
ESH	Electronic Submission Hub
EVA	Emergency Vehicular Access
FGDC	Federal Geographic Data Committee
FS	Fire Safety
FSD	Fire Services Department
GBP	General Building Plan
GFA	Gross Floor Area
GIC	Government, Institution and Community
GIS	Geospatial Information System
GLTMS	Greening, Landscape and Tree Management Section
GNET	Government Network
GOS	GeoInfo OneStop
GPS	Global Positioning System
GPU	Graphics Processing Unit
GSF	Green Space Factor
HA	Hospital Authority
HAD	Home Affairs Department
HD	Housing Department
HKO	Hong Kong Observatory
HKPSG	Hong Kong Planning Standards and Guidelines
HKSAR	Hong Kong Special Administrative Region
HKU	The University of Hong Kong
HKUST	The Hong Kong University of Science and Technology
HSK	Hung Shui Kiu
HyD	Highways Department
IA	Impact Assessment
IAWG	Institutional Arrangement Working Group
ICT	Information and Communications Technology
IDS	Intrusion Detection Service
IFC	Industry Foundation Classes
IMS	Intranet Mapping System
IoT	Internet of Things
IPS	Intrusion Prevention Service
IRN	Intelligent Road Network
ISO	International Organization for Standardization
IT	Information Technology
ITB	Innovation and Technology Bureau
ITF	Innovation and Technology Fund
KPI	Key Performance Indicators
LAI	Leaf Area Index
LandsD	Lands Department
LCSD	Leisure and Cultural Services Department
LiDAR	Light Detection and Ranging
LOD	Level of Detail
LSGI	Department of Land Surveying and Geo-Informatics

LULC	Land use/land cover
LVIA	Landscape and Visual Impact Assessment
MLP	Master Layout Plan
MMS	Mobile Mapping Service
MOOSC	Multi-Level Object-Oriented Segmentation with Decision Tree Classification
NDA	New Development Area
NDVI	Normalized Difference Vegetation Index
NDWI	Normalized Difference Water Index
NGO	Non-Governmental Organization
NIMBY	Not In My Backyard
NTHQ	New Territories District Planning Division Headquarters
OGCIO	Office of the Government Chief Information Officer
OVT	Old and Valuable Tree
OZP	Outline Zoning Plan
PHI	Potential Hazardous Installation
PIA	Pedestrian Impact Assessment
PlanD	Planning Department
PLM	Product Lifecycle Management
PoC	Proof of Concept
POD	Pedestrian-Oriented Development
PoI	Point of Interest
PPGIS	Public Participation Geographic Information System
PRAISE-HK	Personalised Real-Time Air Quality Informatics System for Exposure – Hong Kong
PSI	Public Sector Information
PTI	Public Transport Interchange
QRA	Quantitative Risk Assessment
R&D	Research & Development
RAM	Random Access Memory
RTIS	Road Traffic Information Service
SA&D	System Analysis and Design
SAN	Storage Area Network
SBD	Sustainable Building Design
SDI	Spatial Data Infrastructure
SDO	Spatial Data Office
SGR	Smart Green Resilient
SIMAR	Systematic Identification of Maintenance Responsibility
SMP	Sewage Master Plan
SOA	Service Oriented Architecture
SPP2	Statutory Planning Portal 2
SR	Sensitive Receiver
SSO	Single Sign-On
SST	Smart Sensing Technology
STT	Short Term Tenancies
SUA	Strategic Urban Area
SWOT	Strengths, Weaknesses, Opportunities, and Threats
TCO	Total Cost of Ownership
TD	Transport Department
TIA	Traffic Impact Assessment

TKO	Tseung Kwan O
TMO	Tree Management Office
TMIS	Tree Management Information System
TPEDM	Territorial Population and Employment Data Matrix
TPU	Tertiary Planning Unit
TRA	Tree Risk Assessment
TSTW	Tsim Sha Tsui West
UAT	User Acceptance Test
UAV	Unmanned Aerial Vehicle
UFS	Usable Floor Space
UGS	Urban Green Space
UI	User Interface
URL	Uniform Resource Locator
UU	Utility Undertaker
VIS	Vegetation Information System
VC	Vegetation Cover
VD	Vegetation Density
VM	Virtual Machine
VMHA	Virtual Machine High Availability
VPN	Virtual Private Network
VR	Virtual Reality
WCAG	Web Content Accessibility Guidelines
WG	Working Group
WGPD	Working Group on Population Distribution Projections
WP	Working Paper
WSD	Water Supplies Department
WV3	WorldView 3
XPMS	Excavation Permit Management System
YSI	Yellow Soil Index

1 INTRODUCTION

1.1 Background

1.1.1.1 As announced in the 2017 Policy Address, the Government is striving to promote the establishment of the CSDI to provide B/Ds as well as the public and private organisations with an information infrastructure to share spatial data, support various smart city applications, and the initiatives of the "Smart City Blueprint for Hong Kong" (the Blueprint). The CSDI and the application of ICT have also been recognized as pivot means to achieve the strategic vision to plan Hong Kong as a SGR City Strategy' championed under "Hong Kong 2030+: Towards a Planning Vision and Strategy Transcending 2030" (Hong Kong 2030+).

1.1.1.2 To put forth the development of the CSDI initiative, DEVB in 2018 completed a consultancy study on the overall strategy for the CSDI implementation, which is to formulate an effective the CSDI development strategy for the purpose of land and infrastructure planning development and management in Hong Kong. Meanwhile, PlanD has also embarked on a feasibility study on "Development of a Common Spatial Data Infrastructure - Built Environment Application Platform" (the Study) in March 2018 to explore the establishment of the BEAP and use of spatial data in developing built environment applications, following the development strategy of the CSDI.

1.1.1.3 This Assignment aims to take forward the CSDI development strategy and support the Blueprint, the Hong Kong 2030+, the built environment related CSDI initiatives and other relevant studies' recommendations, by formulating an overall development framework covering different key aspects in the short, medium and long term and demonstrating with test case through proof of concepts and prototypes of a number of applications for the establishment of the CSDI BEAP focusing on city planning, infrastructure/engineering, and environmental applications. This Assignment, other than examining feasibility, also serves as a demonstration case of CSDI to further support and provide early delivery of tangible benefits to users.

1.1.1.4 The BEAP aims to foster co-operation, collaboration and co-creation with Government departments through application and data/information sharing, and knowledge building for mutual benefits, before extending to business, academia and the public. It is expected that the BEAP would provide a number of common and thematic applications for users to conduct analysis to support the work of B/Ds.

1.1.1.5 The BEAP will focus on key aspects of the built environment applications in relation to city planning, infrastructure/engineering, and the environment of Hong Kong, in particular those under DEVB, and cater for short, medium to long term development. It is understood that data and application need to be integrated together in order to maximize the meanings they bring, therefore under the CSDI initiative, the BEAP would improve efficiency, transparency and the support for decision making in planning and development, and hence, fostering interdepartmental co-operation and synergy for policy formulation, decision making, resource management, efficiency as well as the delivery of high quality services to the public (**Figure 1.1**).

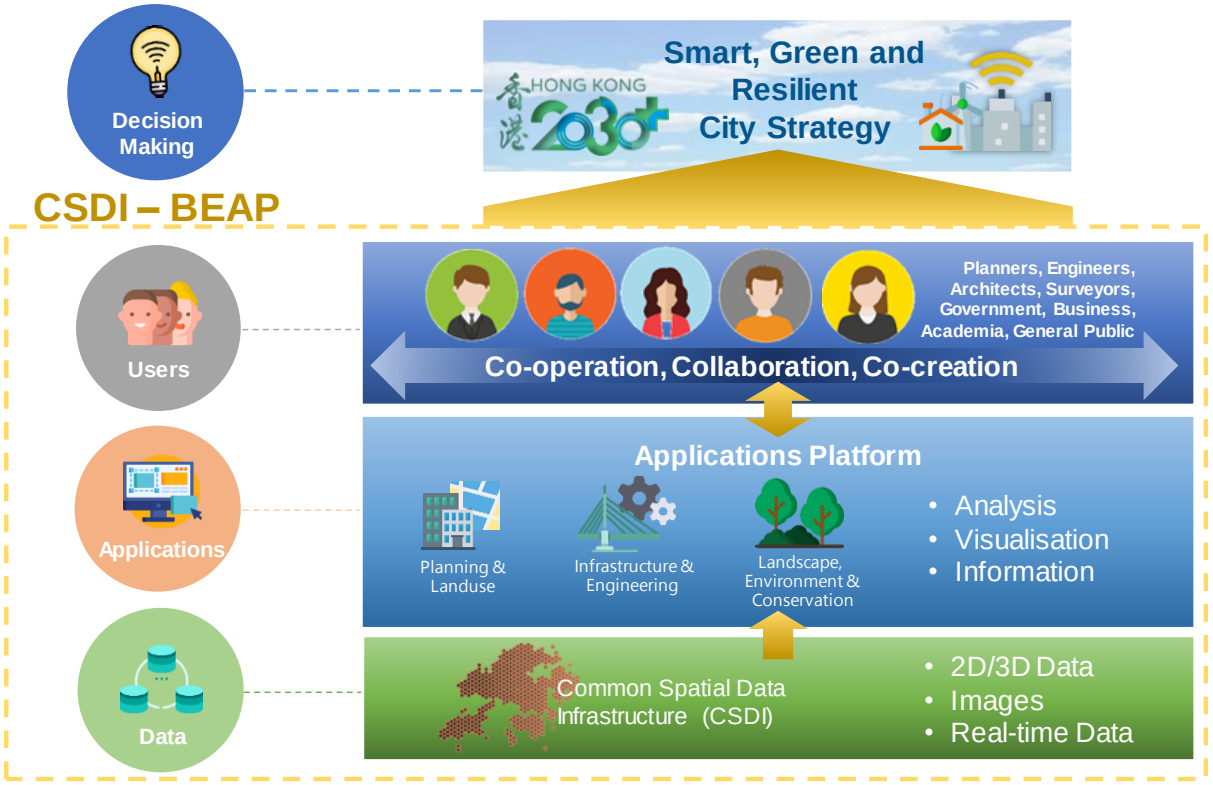


Figure 1.1 – CSDI – BEAP Study

1.2 Study Process

1.2.1.1 PlanD commissioned Ove Arup and Partners Hong Kong Limited (the Consultant) on 5 March 2018 to undertake the Study. The assignment comprises two study stages. Stage 1 is the study and formulation of a development framework and Stage 2 is the development of a test case for the BEAP.

1.2.1.2 Key tasks for Stage 1 include:

a) conducting a desktop review of built environment application platforms and systems implemented or being implemented by other international smart cities, governments and agencies, and/or public service operators that are related to city planning, infrastructure/engineering development and the environment; and

b) formulating an overall CSDI BEAP framework with goals and targets as a roadmap covering short, medium and long terms for the gradual implementation of the CSDI and smart city initiatives, identifying potential built-environment related applications, formulating the BEAP development plans with objectives, scope, applications, technology development, and implementing and phasing to enable the gradual implementation of the BEAP in short, medium and long terms.

1.2.1.3 The conceptual model of the BEAP was developed in the course of formulating the overall CSDI BEAP framework based on the four building blocks and corresponding principles as derived based on the findings from the Desktop Review and stakeholder involvement. Based on departmental visits to B/Ds, selection and prioritization criteria and subsequent synergy workshop and

stakeholders' engagement meeting, potential application types were then identified for further investigation and development.

1.2.1.4 Stage 2 formulated and established a test case for the future development of the BEAP to demonstrate that the identified applications could be applied to support work of B/Ds through proof of concept and demonstrate the feasibility through prototyping of applications for the future development and implementation of the BEAP.

1.3 Structure of this Report

1.3.1.1 The Final Report summarises the findings throughout the course of the Study and comprises the following elements:

- **Chapter 1** provides an understanding and appreciation of the Study;
- **Chapter 2** reviews the international and local experiences on built environment application platforms and associated applications;
- **Chapter 3** outlines the development framework of the BEAP and its four building blocks;
- **Chapter 4** presents the 30 PoCs and 10 prototype applications developed throughout the course of the Study;
- **Chapter 5** elucidates the implementation strategy and requirements of the BEAP at platform level and application level;
- **Chapter 6** concludes and summarises the findings of the Study.

2 REVIEW OF INTERNATIONAL AND LOCAL EXPERIENCES

2.1 Desktop Review on International Case Studies

2.1.1.1 The consultancy study started with a desktop review of the BEAP and systems implemented or being implemented by other international smart cities, governments and agencies, and /or public service operators relating to city planning infrastructure/engineering and the environment.

2.2 Scope of the Review

2.2.1.1 The focus of the review is on the BEAP, and associated applications that have been deployed by other cities and agencies to support planning and infrastructure development. In particular, the focuses of attention are on:

- The business purpose and services of the platform (including applications provided);
- The functionality and potential value of the services to the BEAP;
- Implementation process and phases (where known);
- Key dependencies for the platform to function effectively;
- Any lessons learned in relation to the above.

2.2.1.2 The review concentrated on application platforms that address the following built environment application themes:

- Planning and landuse;
- Infrastructure and engineering;
- Landscape, environment and conservation.

2.2.1.3 The focus was on planning for the built environment, rather than specific lifecycle phases of asset design, construction, operation, maintenance, and decommissioning. In considering the needs for planning we have included applications for scenario modelling.

2.2.1.4 Our reviews considered any platform developed to support the built environment and, in line with the objectives of this study. We were particularly interested in platforms that enable collaboration between Government B/Ds as well as with the business, academia and the public, with the objectives of improving:

- Policy formulation;
- Decision making;
- Resource management; and
- Services to the public.

2.2.1.5 Improved collaboration in this way is regarded as essential in addressing Hong Kong's Smart City objectives of:

- Improve quality of living;
- Improve sustainability;
- Improve efficiency of resource utilisation;
- Improve city efficiency;
- Improve climate resilience;
- Improve Hong Kong's attractiveness; and
- Promote a low carbon, smart economy.

2.2.1.6 The following have also been considered: governance / institutional arrangements; policies and procedures; data sources, formats, management and sharing; data access rights and agreements; application of standards; system architecture and supporting technologies (e.g. proprietary, open, custom-built, interoperability, and scalability); and security considerations.

2.3 Selection Criteria for International Case Studies

2.3.1.1 The Consultants have focused their review on three principal international case studies: Singapore, Australia and Portland of the USA. In addition to these examples, additional international best practice examples from other cities or government agencies (e.g. New York, London) which have relevance to the Hong Kong BEAP have also been drawn upon. The details findings of the three case studies can be found in Chapter 3 to 5 of the "Final Technical Report on Desktop Review" of this study.

2.3.1.2 In selecting these case studies, the following criteria were used (in order of importance):

- Relevance to the Hong Kong BEAP – i.e. whether it performs the same or similar function to that proposed for the BEAP;
- Relevance to the Hong Kong conditions – i.e. whether the platform belongs to a city with similar geography, population, political structure, planning challenges, etc.;
- Whether the platform has been acknowledged by others as an example of best practice;
- Platforms with varying implementation characteristics to enable comparison of the different approaches that have been taken;
- Whether the platform and/or responsible authority offers useful lessons for Hong Kong; and
- Availability of key information about the platform and its applications – i.e. whether the information needed can be obtained from publicly available resources, including independent reports or articles about the platform; whether additional information from the platform operators/responsible authority were available for collection.

2.3.1.3 The three case studies including Singapore - Virtual Singapore, Australia - Australian Urban research Infrastructure Network (AURIN) and Portland - Corporate Geographic Information System (CGIS) provide a broad coverage of

different implementation approaches. In reviewing the strengths and weaknesses of each, the approaches taken by the case studies have been compared and contrasted in relation to the ambitions of the BEAP to identify lessons that can be learnt.

- Virtual Singapore: a recent city-wide implementation with a focus on 3D data and city model to specifically address built environment issues. It employs a proprietary technology platform that is hosted in the cloud environment.
- AURIN: a national urban information and applications platform driven by academia. It is characterised by the federated nature of the participants, the use of open source technologies and internal self-hosting model.
- CGIS: a successful long running city-wide programme that took a centralised approach, uses commercial software running on a mix of in-house and cloud hosted services and has embraced an open data approach to collaboration.

2.4 International Case Studies

2.4.1 Virtual Singapore – Singapore

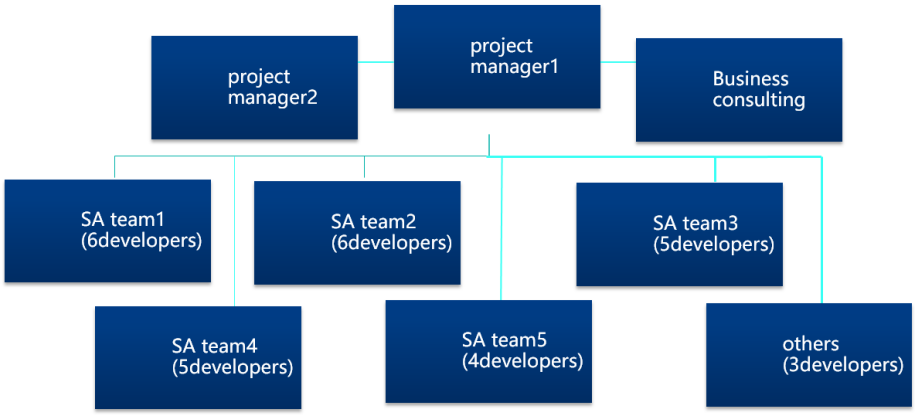
2.4.1.1 Virtual Singapore is championed by a National Research Foundation (NRF), as well as the government's land authority and technology agency. NRF will be leading the project development, whilst the land authority will support with its 3D topographical mapping data and become the operator and owner when Virtual Singapore is completed. The technology agency will provide expertise in ICT and management as required in the project. There are ongoing collaborations with government agencies, universities and partners to leverage this platform for their modelling and simulation needs.

2.4.1.2 As part of Singapore's "Smart Nation" strategy, the main goal of Virtual Singapore is to develop a common data exchange platform, making much of the data that already exists in government ministries easier to be accessed and shared in a secured and controlled environment. Visualization is a major goal of the project so that the aggregated and integrated data from different sources including BIM and GIS, can be "seen" in an object based virtual 3D model. Based on the 3D visualization on one platform, it can offer additional benefits to enhance collaboration, simulate scenarios on underground and coastal expansion, and increase communication across government departments and public communities, etc. **Table 2.1** illustrates the best practice and lessons learnt from Singapore's CSDI and BEAP.

BUSINESS ARCHITECTURE *The Business Architecture view looks at the corporate aspects of the platform such as how it fits within the organisation, the services and products it provides and how it operates.*	
Business services provided by the platform A description of the business services and products	Virtual Singapore aims to assemble and analyse data that already exists in dozens of government agencies, plus new data collected in real time from smartphones, cameras and sensors, such as wind, air quality, temperature, humidity, noise, etc., to model and predict solutions to the emerging and complex challenges Singapore faces. Displayed in the context of a virtual 3D model of the city, Virtual Singapore will enable city planners to test various responses to everything from population growth and resource management to public events and building patterns, and implement those that create the safest, most positive experiences.

provided by the platform unit/organisation such as: spatial data provision, data brokerage, analysis, software provision/sales, user training, etc. Who is the target audience for the platform?	The concept of this project combines several hot technological trends, including big data, the Internet of Things, 3D modelling and predictive analytics. The model will provide information to four basic constituencies. By providing a digital reference, the solution enables users to: • Holistically model and integrate the various systems within a city • Map, visualize and comprehend the effects of urbanization on resources • Develop new methods and real-time collaboration between different disciplines • Strategize and optimize urban and territorial planning • Model new city governance • Integrate new networks and infrastructures (e.g. transportation, energy, telecommunications) • Dream, imagine, simulate, analyse and design the living environments of the future The platform developed by Singapore is serving not only government agencies, but also public citizens, businesses and researchers. It is a platform where people could have access to limited data and they could use applications that make their lives much more convenient. Businesses also can offer targeted services to their customers. And the last stakeholder group is researchers, who may have more ideas than government bureaucrats about how to create new technologies and services. In order to support the innovation and the training on this platform, considering the large-scale number of trainees, the government bureaus are working with training agencies with teachers in the city. Trainers have been trained by the solution provider and delivered by a group of around 20 people in each department by priority to provide inspiration on the on-going transformation and develop a collaborative new way of application development on top of the platform to be used by each department. Supported by relative vendors, the qualified training agencies have standardised and regular training for the target audience.
Legislation, policies and procedures Are there any specific legislation, statutory instruments, guidance, policies or procedures in place to facilitate the platform?	The industry-leading functionality of 3D virtualization is one of the core foundations of this project. In order to support standard as BIM and GIS, all sources of data are structured by the core capabilities of the platform (scanning, Lidar, BIM, Shape files, etc.). Singapore has chosen industry standards such as CityGML and IFC to cover city and building graphical data exchange and pdf as non-graphical data exchange. Real time data collection & communication is based on industry standard RESTful API. To ensure the exactly and update level of geographical/non-geographical data, a data update process has been setup to support this requirement.
Performance management / KPIs How does the unit/ organisation measure its performance against targets and what key performance	This information was not disclosed by Singapore.

indicators does it use for each of its services / functions.	
Governance / institutional arrangements How does the unit/ organisation fit within the organisation (or is it an independent organisation) and what governance arrangements are in place?	The project was launched by the National Research Foundation (NRF), a department within Prime Minister's Office that develops policies, plans and strategies for research, innovation and enterprise, as part of the country's "Smart Nation" multi-year technology development program. The NRF leads the project, while the Land Authority provides 3D topographical mapping data and will own and operate the project once completed, and the Information Technology department (Government Technology Agency) provides ICT expertise. Other public agencies will participate in this project in various phases. National Research Foundation (NRF) is governed by the Scientific Advisory Board (SAB), which is a multi-disciplinary international board with expertise in broad areas of technology. The project is divided into two phases. Each phase is 3 years (2x3 years), starting from the end of 2014. The target of the first 3 years is to build Virtual Singapore, the next 3 years will use Virtual Singapore as the platform to develop new applications in order to support and improve the city operation, city maintenance, and smart city project research. This project will offer a rich data environment for long-term decision making purposes that will affect the population and land area, including infrastructure and resource management, environmental and disaster management, public services, urban planning, community services and homeland security. A deployment team has been localized in Singapore working jointly with the customer. Project team has a long term assignment to the program with weekly management review. Quarterly executive workshops are performed with all project stakeholders to review the timeline, the roadmaps and the project issues, including relevant departments. And semester review is organized with the Singapore executive leaders.
Staffing / resourcing Does the unit/ organisation have dedicated staff; how many people are involved and what roles do they have?	Since the very early stages of the Virtual Singapore, a total of 70 professional specialists has worked together to develop and test the Virtual Singapore vision and concept. During the 3 years of development, a dedicated team has been working around the clock to test and challenge the possibilities of each requirement. The team in Singapore consists of a sales team and senior technical consultants who seek innovative ideas among agencies to perform proof of concept for feasibility study. At the back end there is a R&D Virtual Singapore team responsible for the development of new functionalities to fit uses' requirements. The government has commissioned one software company & lead consultants to lead the solution design & development works. The team has a group of experts such as GIS, BIM, IT technology and others, to work with government business domain experts in this project. As to the staffing size of the software company, it includes dedicated Project Manager, Solution Architect (for solution Platform, GIS and BIM), Software Developer and other domain experts in this project:

	 The core specialist team of Virtual Singapore consists of around 15-20 staff members, subject to the development of the project: **Project Manager** – responsible for schedule, milestone, issues, risk tracking **Business consultant** – transform and inspire innovative ideas into workable use cases with vision and KIP towards smart nation initiative. **Solution Architect** – engaging on technical solutions towards each use case. **Referential Developer** – managing geospatial data and 3D data conversion used in 3D referential. **Widget Developer** – application specific customization in connection with 3D referential. **Headquarter R&D City Specialists** – technical support for new functionalities and platform support in sync with Singapore team
Funding model How was the development funded and how is its operation funded? How are individual products and services charged for? Is the business case for the establishment of the platform available? What are the on-going costs of operating the platform?	The project is a 6-year transformation program to create an intelligent information platform that will be used by citizens, businesses, government and research community to solve its emerging and complex urbanization challenges. The (National Research Foundation) NRF as stated in its mission, is leading and funding the project. Platform virtual twin is accessible to all departments and each department is afterwards in charge to fund their licensed application usage.
Usage agreements and licensing What service agreements	The non-disclosure agreements (NDAs) and service agreement SOWs (Scope of Work) were signed between the lead consultant, Software vendor, Data provider and APP end user for data accessing, APP customization & developing and platform maintenance.

and/or licensing is used when accessing the platform services and data? Are there Service Level Agreements in place for the provision of the platform services?	The project's 3D visualization capability is based on one mature platform from the software vendor, with usages licensed granted to each platform end user, including the department/agency administrators, department/ agency users and the citizens.

APPLICATION ARCHITECTURE

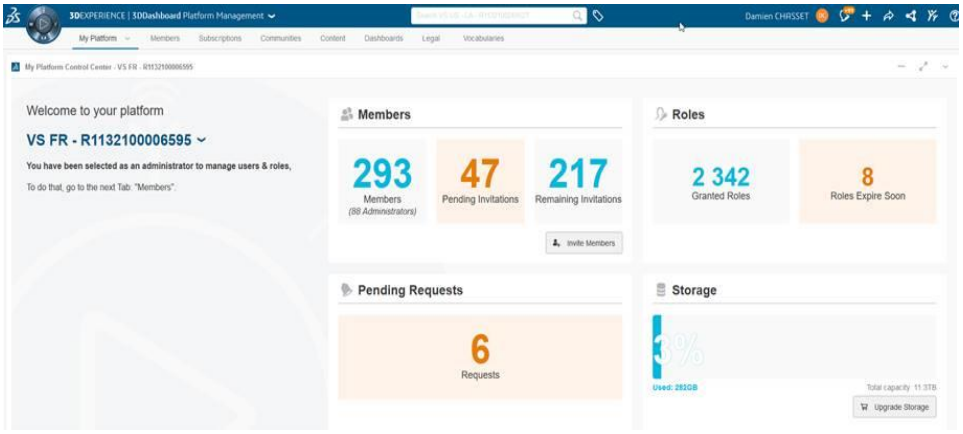
The Application Architecture view considers how the suite of applications work together to provide the business services described above, as well as the supporting 'back office' applications required to deliver those services. This view is not concerned with any single end user application but rather on how the platform is constructed.

System architecture / technical building blocks Describes the major components of the platform infrastructure and how it relates to other systems such as an underlying Spatial Data Infrastructure (SDI). This section should also consider licensing models/costs in cases where proprietary software is used within the platform.	This solution provides the ability to model, analyse, simulate, visualize and experience the complete cities in a virtual environment, and the use of 3D visualization offers additional benefits including the enhancement of collaboration and communication across government departments and public communities. The solution natively supports standards such as Building Information Modelling (BIM) and Geographic Information System (GIS), and provides digital and accurate virtual model of the entire city, is called 3DEXPERIENCity. It is based on DS 3DEXPERIENCE platform. The platform comprises mainly the following components or services: - License Control, based on the Platform License Server - Passport: provides authentication and single sign-on (SSO) services for the whole platform - Dashboard: brings information from diverse sources into one customizable web page - Search: federated indexing services - 3DSpace: simplified, management of data and content, including unified access to all integrated applications plus 3rd party apps, and indexing of 3DSpace Index objects and 3D indexing, - Social community application: enables cross-discipline collaboration of users anywhere in the extended enterprise - Comment application: provides the ability to interact with other platform members by liking content and adding comments to any item - Notification application: gives platform users timely updates about activities going on. Each user in the platform has a user license granted according to his profile which takes into account his relevant experience and platform roles. To support the application development in Virtual Singapore, the Virtual Singapore Platform uses Java APIs and REST Web Services for web-based Application development to support the application development in Singapore. This specialized Application development in the Virtual Singapore Platform is called Widget development. It is based on the latest Web Standard Technologies and supports the application to visualize External content from any source (Internet, or Customer legacy content), or visualize and edit internal content managed by the Virtual Singapore Platform services. So developers can use Widget Technology to develop Applications making full of external and internal data information on the Virtual Singapore Platform.

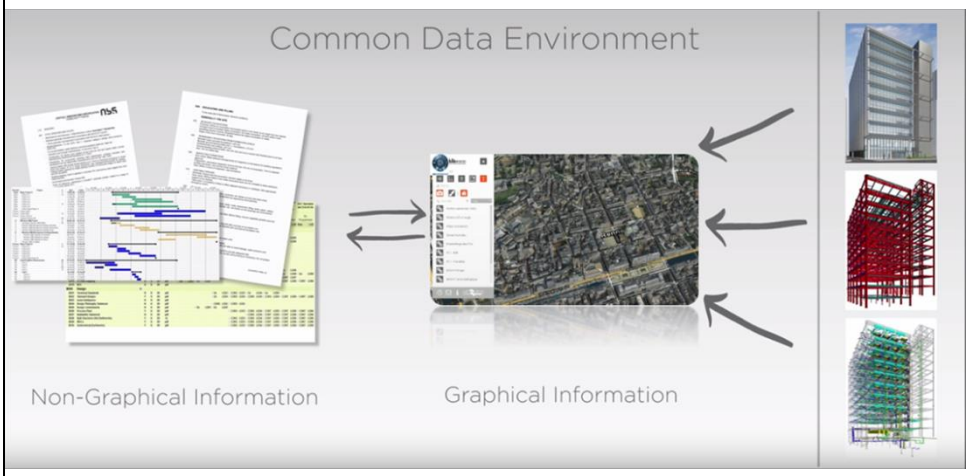
	The Virtual Singapore Platform is a configurable and customizable platform with a wide range of applications: - The 16,000 C++ Services available for Applications installed on the Native Client - The integration of major software and Third Party Applications - The integration and interoperability with heterogeneous systems - The compliance to standards - The framework for partners defining the rules to develop applications or interfaces compliant with the Virtual Singapore platform architecture
Applications deployed Describes both the core application components of the platform itself, as well as identifying some of the end-user applications that are supported by the platform. Does the platform present Read-Only data or does it support data creation and update as well?	The project uses both data gathered from various public institutions and data collected in real time. The platform serves as a single point of access for content and applications originating from several sources, in multiple formats. The content can be real-time, proprietary, open data, system-based, or from connected objects. The platform has a cross-cutting role with respect to different data found in the city. It connects actors and usually silo data. This enables greater consistency in the actions of foreshadowing of the future planning and better coordination of actions. The digital Twin application serves as the main visualization and query platform for the data obtained from different sources in near real time or pre-processed mode. In order to support different end-user applications, the spatial area will be modelled in Levels of Detail (LOD1-2) for innovative applications, here is a list of the applications, detail description will be in the application examples section (Sec 3.3): • Mobility and Accessibilities • Science Experiment • Public Transportation Optimization – MRT and Bus Stop • Geological Propagation Model – For industrial real estate development, offshore area
Support for collaboration and public engagement The focus we are particularly interested in is how other platforms have enabled collaboration between departments, public sector, academia and the public.	The platform is a scalable web-based platform enabling all identified roles/users to collaborate on a secured and unified environment with relevant authorizations and lifecycles. The platform incorporates index and search capabilities on diverse data sources from government, researchers, businesses and citizens, including structured, non-structured, temporal, real-time, social media feeds, simulation results, etc. The platform supports data discovery, versioning, time-stamping, life-cycle management and collaboration capabilities. Virtual Singapore provides a wide range of capabilities for extended ecosystem collaboration between government (Singapore agencies), researchers, businesses and citizens. Those capabilities include the ability to manage and organize shared documents and structured product data. This virtual collaboration environment allows one team to engage securely similar to traditional office environment. Users can create a collaborative digital workspace for anyone who has access to the platform. A workspace can be used by geographically distributed team members who offer expertise from various disciplines such as civil engineering, urban planning, maintenance and operation, event management and security. Within those secure workspaces, members can create folders; organize, view, review, mark-up and approve documents and other product data, subscribe to event notifications, and schedule meetings. Collaborators can maintain and share content for improved decision-making and issue management. Automatic notifications help team members monitor milestones associated

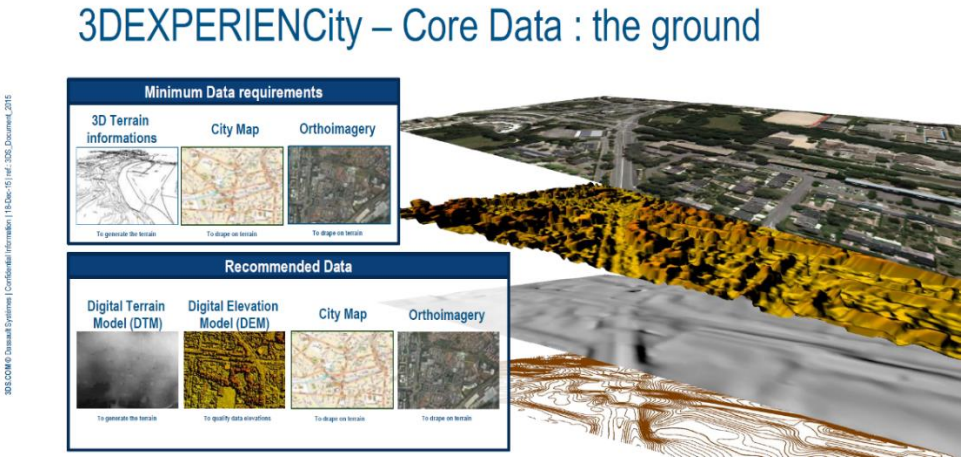
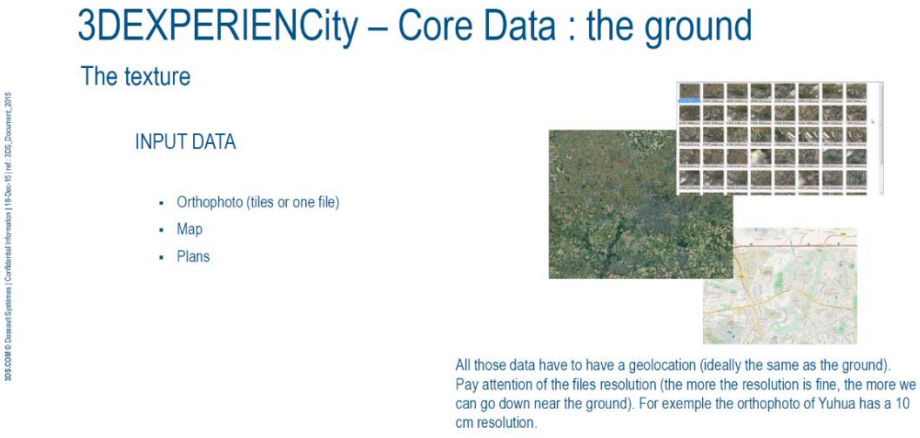
	with lifecycle management and acquiring approvals. Discussion threads enhance collaboration by maintaining an accurate record of the conversations. The application" Mobility and Accessibilities" is a good example for collaboration, when designing and constructing a new Pedestrian Overhead Bridge (POB), urban planning for public facility, park management and construction companies are working together via collaboration workflow in order to reveal area of interferences, non-conformance and potential conflicts in design, to avoid unnecessary budget spending and raised the issues in advance. As a collaborative platform, Virtual Singapore will allow communities to co-create and improve the city environment and their neighbourhoods. From choosing the colour of paint for a public housing block to locating new facilities such as basketball courts, parks and function rooms, it serves as a useful and convenient platform for individuals to make collective decisions. With proper security and privacy safeguards, Virtual Singapore would enable public agencies, academia and the research community, the private sector, and also the community to make use of the information and system capabilities for policy and business analysis, decision making, test-bedding of ideas, community collaboration and other activities that require information: • <u>Government</u> Virtual Singapore is a critical enabler that will enhance various Whole-of-Government (WOG) initiatives (i.e. Smart Nation, Municipal Services, Nationwide Sensor Network, GeoSpace, OneMap, etc.). • <u>Citizens and Residents of Singapore</u> Through Virtual Singapore, the provision of geo-visualization, analytical tools and 3D semantics-embedded information will provide people with a virtual yet realistic platform to connect and create awareness and services that enrich their community. • <u>Businesses</u> Businesses can tap on the wealth of data and information within Virtual Singapore for business analytics, resource planning and management and specialised services. • <u>Research Community</u> The R&D capabilities of Virtual Singapore allow the creation of new innovations and technologies for public-private collaborations to create value for Singapore. Amongst other new research areas, semantic 3D modelling is an emerging area, where research and development is needed to develop sophisticated tools for multi-party collaboration, complex analysis, and test-bedding.
Application Programming Interfaces (APIs) provided How are the services of the platform exposed to support end-user application development	One of the major purposes for this platform is to encourage the innovative smart city solution development. Partners, science institutes or universities can develop business applications that exploit data from single repository to make the city smarter, greener and more resilient. On this platform, there is API allowing you to create: • Automation macros in VBScript, VBA, C#, and VB.NET. • Web and widget applications in JavaScript. The dashboard app is an application represented in the browser/web interface with a title, an icon, a tooltip and pointing to a JavaScript application. Such JavaScript applications are named widgets. The main approach for integration with the solution is to develop such widgets. Widgets may be considered as downloadable applications which look and act like traditional apps but are implemented using web technologies including Javascript, Flash

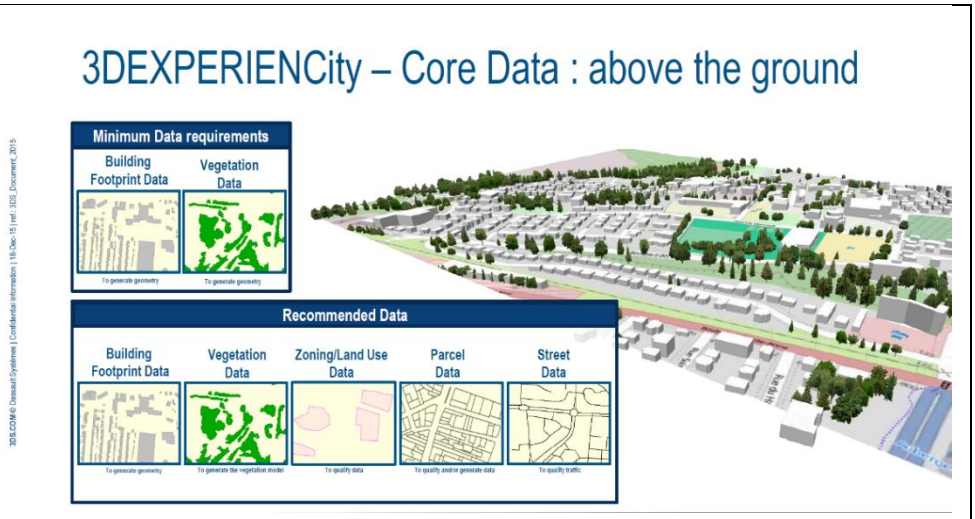
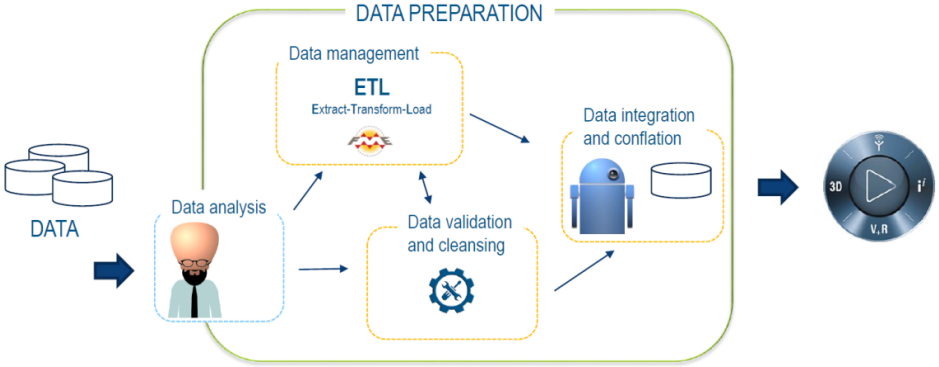
and what APIs and languages are supported?	and HTML. Typical examples of a widget will be: point to and select one camera object on 3D referential, right click and displaying/showing live video of this camera.
Channels Through what mechanisms can users and applications interact e.g. web, mobile app, desktop application, face to face service desk, kiosks, custom devices, etc?	Virtual Singapore will be able to be accessed on solid state engineering machines and mobile devices like smartphones and tablets. Users can access the platform and related APPs through SSO login with different roles.  Typical UI of platform webpage  Applications can be leveraged across multiple devices and operation systems.
Technologies What technologies / products have been used to develop the platform infrastructure and are they vendor proprietary, open source, custom-built?	This smart city platform has completed architecture of PaaS and SaaS layers. The platform includes different kinds of core services and provides APIs to integrate with different platforms with different data formats. The platform has SSO security system to manage different end user roles and logins and could be deployed on IaaS cloud infrastructure with software provider's certification.

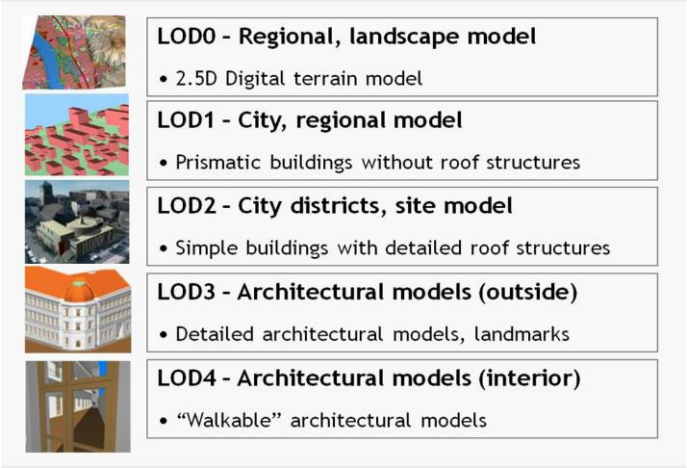
Interoperability, use of standards What technical standards have been adopted to enable a broad range of technologies to interact with the platform?	The platform comes with core capabilities such as geo-location of information, Spatial indexing system, unified database, routing, and LOD management system. During the digitalization phase (including existing data collection), all sources of data are structured by the core capabilities of the platform (scanning, Lidar, BIM, Shape files, etc.). Singapore has chosen CityGML and IFC supports standards to cover city and building graphical data exchange and pdf as non-graphical data exchange.
Security How have security mechanisms been implemented to protect the platform and to authenticate users and manage access privileges?	To access the platform, each authorized end user connects to the platform through a username and password, they then access to data and applications corresponding to its role in the ecosystem of the city. Different roles have different authority to access the data on the platform. An inhabitant does not see the same information as an official, a member of public city services, a business actor or a researcher. Take "City Contributor" and "City referential manager" role as an example. "City referential manager" role has all the authority to create, search, modify, and manage all the 3D data on the platform, but "City Contributor" role could only search, upload the 3D data but could not create or modify 3D data on the platform. When users login the platform with different roles, they see different information on the UI. Everyone can take action and get the information they need and work with all the other players with whom they are related based on their role within the city ecosystem.
Platform monitoring and administrative functionality What functionality has been implemented within the platform to monitor service provision and system health, as well as to support administrative tasks such as usage throttling, fee collection, adding new services and updating existing services?	The solution and the platform can be deployed on public and on premise cloud. For Singapore, currently the solution is being run on government premise cloud. In order to support its vision of giving access to citizens/ visitors, igniting the innovation based on this platform, they are planning to deploy the solution on Public cloud. Since this is a cloud based solution, all Supervision and Operation will be done for the customer including Monitoring, Licensing and Upgrades. The software vendor will be responsible for cloud platform maintenance and support 24/7/365. For the On-Premise cloud solution, the software platform vendor could provide remote maintenance to keep the system stable, and upgrade the system. The platform has a dashboard as shown below to monitor the platform provision and services status  Monitoring platform provision The above figure shows the platform monitoring functions. The customer's platform shows how many roles were licensed to end customer to use the platform. Customers could have many same roles for different end users to login platform for daily work.

DATA ARCHITECTURE *The Data Architecture view considers how the data is organised and how the appropriate data is presented to end users and systems. We are interested in the relationship between the application platform and the Spatial Data Infrastructure and thus (if relevant) the data view should consider the distinction between raw/source data from business systems, etc, and the data that is presented to the platform end-user applications. In those cases where the platform is responsible for presenting tailored information products by processing source data sets then the products and production process should be described where possible.*	
Information products / data enrichment Identifies the information products that are presented by the platform as well as describing any processing and enrichment of source data to produce a data product that is re-purposed / tailored for built environment applications.	The ability to model, analyse, simulate, visualize and experience complete cities in a virtual environment is at hand, the use of 3D visualization offers a critical additional benefit: ● it greatly enhances collaboration and communication across disciplines and communities ● It offers a unified collaborative environment for the Cities, natively supporting standard as BIM and GIS. The solution provides a holistic digital and accurate virtual model of the entire city. It comes with a multi LOD representation of the city, from terrain to city blocks, building façade and roof structures as well as architectural details e.g. walls, windows, doors and building interiors. Digital models of the city are managed and presented in a seamless and integrated manner, for visualization, analysis, modelling and simulation applications.
Data access rights and agreements This section identifies the types of data agreements between the data providers and the platform provider.	Geographic data and non-geographic data are shared between data providers and software/solution providers under NDAs. Also, Data access right policy is defined to cover the level of security linked to government governance (public, restricted, confidential). With different platform roles, end users can only access the APPs or data related to their role functions. The platform also has a Passport function to provide a secure Single Sign-On environment for the entire platform. Each end-user has their own user account /password with roles configuration. The model is based on sources including authorised data from different state departments. With images and data collected from various public agencies, including geometric, geospatial and topology, as well as legacy and real-time data such as demographics, movement or climate, Virtual Singapore users will be able to create rich visual models and realistic large-scale simulations of Singapore. Users can digitally explore the impact of urbanization on the city-state and develop solutions that optimize logistics, governance and operations related to environmental and disaster management, infrastructure, homeland security or community services.
Data sources, formats and management When relevant, identifies where source data has come from and	City information includes graphic data and non-graphic data. The solution in Singapore is a 3D collaborative environment where data from sensors and city systems are federated into a virtual referential model that benefits everyone. **Graphic data:**

how it has been exposed to the application platform.	Data source could be local urban planning, construction service provider, city planning department, System integrator who has the capability to collect the graphic data. Graphic data normally include: - A DTM for the terrain - The 2D digital cadastral view of Singapore - The footprint of the buildings - 3D Representation of the buildings following quality criteria provided by platform software vendor - BIM data - GIS data - The list and position of the Point of Interest (POI)s to be represented **Non-Graphic data:** Non-graphic data could be urban design requirements, city space information, planning data, and all urban vertical subsystems such as transportation, environment, water treatment, utility, construction, which contains project plans, building materials, engineering, human resources, etc. The data source of non-graphic data depends on the data owner, for instance, city design rules of city master planning from city design institute or urban planning department. IoT data from vertical IoT system management department, transportation data from transportation department, solar panel energy and devices status data from green energy companies, etc.  Virtual Singapore also follows Open Geospatial Consortium standards formats for 3D buildings and assets such as CityGML, which is a widely used format to exchange data with most building scanning companies. Singapore has set out to use CATIA 3dxml format as the primary format for dealing with existing BIM. Since BIM models are created with various kinds of CAD tools that are stored in different formats, the BIM models can utilize the platform converter tools to allow most major CAD tools to be converted to 3dxml format for 3D referential city user cases.
Foundation datasets, reference geographies	To prepare the virtual city referential using the 3D applications, different types of data need to be prepared and processed before merging with the application. For example: ● Ground Data ■ Digital Terrain Model (DTM)

Identification of the fundamental reference datasets that are used to register other datasets; this could include administrative areas, statistical units, official name gazetteers, etc.	■ Digital Elevation Model (DEM) ■ City Map ■ Ortho-imagery ● Above the Ground Data ■ Building Footprint ■ Vegetation ■ Zoning/Land Use ■ Parcel ■ Street The types of data depend on how much detail and information the end users want to have in the city referential.   Core data: The ground

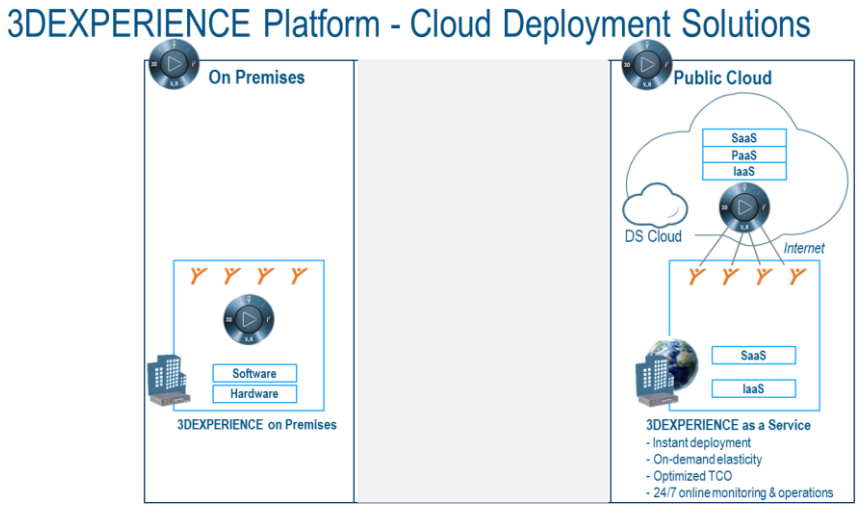
	 Core data: Above the ground: For all the other city facilities, geographic data, underground utilities, this platform could use data with different format, GIS, 3D Terrain， DTM, DEM, Orth imagery, BIM, IFC, CityGML, 3DMax, CATIA, etc.
Data quality assessment / suitability assessment Describe if / how data quality assessments are conducted prior to serving data via the application platform. This could also include consideration for how platform users might assess the suitability of a dataset or service for their particular use.	Source data quality & preparation process are the key parts to ensure a smooth build-up of city referential, the lead consultant have setup a standard procedure to assess the quality of the data prior to building the city referential and a training for end users on how to create qualified source data. As suggested, the data should be extracted, transformed, analysed, cleaned and validated by data specialists before importing to the application. 
Support for personal privacy Describe the steps taken to protect personal privacy, particularly	To access the solution, each authorized personnel connects to the platform with a username and password. He then has access to data and applications corresponding to his role in the ecosystem of the city. An inhabitant does not see the same information as an official, a member of public city services, a business actor or a researcher.

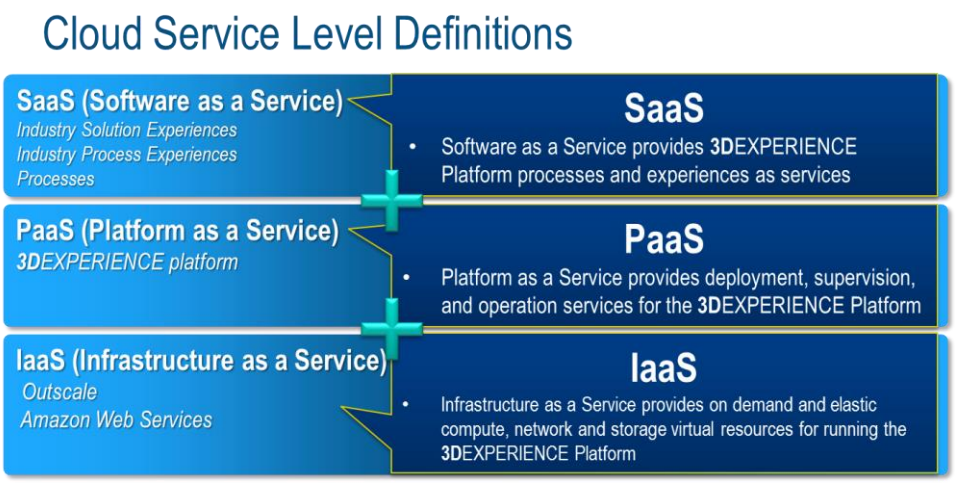
when generating information products from several data sources where there is a risk of exposing personal information through data aggregation.	Everyone can take action and get the information they need and work with all the other players with whom they are related to base on their roles within the city ecosystem. The solution is a cloud based application, it complies with ISO 9001:2015 Software and Operation security certification. P&O mechanism is compliant with ISO 17799 (Aerospace/military norm, which has the highest level). Also the Cloud IaaS providers are certified with ISO27001:2013.
Data model standards Identification of the use of any published data models and lessons learnt from the ways data in which data is presented or described. If the platform supports data creation and data updates, then how is this managed and where is the data stored?	The solution provides a horizontal approach powered by the platform that links all stakeholders in a collaborative working environment and enables access to a single data referential, which dynamically updates as new data becomes available. Consequently, data is exchanged and turned into information, in the literal sense of the word—it takes form. The platform's horizontal architecture is an integrative environment directly linked to the dynamic data referential that powers the modelling, analytics, simulation and visualization of the city in its past, present and future states. It aggregates all the data of the city. These data are the raw material from which the city is built and operated virtually. The virtual representation of the city is managed in time to let everyone know which version of the data it consults. The 3D model of the city is modelled from 3D geographical data. The topography is taken into account as well as the volume of buildings. The level of precision and realism is dependent on the quality of existing data. Each new data acquisition provides an update of the model that covers the entire territory. The platform is able to have multiple representations of buildings through different LOD, below representation describe the composition of each level.  BIM models or realistic models are integrated into the overall model to increase the LOD and realism where needed. 2D map data is stored in the centralized repository and are crossed with the 3D model. This allows, for example, users to see the cadastral parcel boundaries and the position of street furniture (fire hydrants, etc.) in the virtual representation.

	This referential allows a single version of truth and a 3D interactive map in which every object is geo-localized. Thus every asset of the city is provided with an ID Card in which is filled with contextual and relevant information. This platform comes with core capacities such as geo-location of information, Spatial indexing system, unified database, routing, and LOD management system. During the digitalization phase (including existing data collection), all sources of data are structured by the core capabilities of the platform (scanning, Lidar, IFC/BIM, Shape files, etc.). All 3D city data are stored on cloud, which could be public, private or on premise. The platform provides tools / applications to create, view, update, compile, maintenance city 3D model data. Normally, for City IoT data such as parking, security, environment, energy, etc. are store in each vertical sub systems or platforms. The platform can integrate with these IoT systems or platforms to collect, visualize and analyse city IoT data based on users' requirements.

TECHNICAL ARCHITECTURE

The Technical Architecture view considers the physical IT infrastructure elements such as the servers and networks that host the platform. Whilst much of this detail is of limited interest in this desktop study, we are interested in general trends that may be relevant to the development of the BEAP.

Cloud hosted vs on premise Describe how the application platform is physically hosted, in particular which elements may be cloud hosted and the rationale for that.	Designed and developed based on mature technology, the solution and the platform can be deployed as on public cloud solution or on premise solutions:  The platform is a PaaS platform. The solution as the SaaS Applications can be provided on top of PaaS.

	 This architecture is easy for users to deploy the platform and to expand the solution for future applications. Also, cloud architecture key values are: • Instant deployment and scalability • Cost-reduction • Automatic Release Management • 24/7/365 Support and Operation
IMPLEMENTATION AND USER CONVERSION *What lessons can be learnt about implementation and user conversion aspects of the case study platforms?*	
Implementation process and phases Identification of the history of platform development / evolution and the business drivers of each stage	Information was not available
Uptake / change management Identification of any specific actions that were taken to encourage the adoption of the platform and their success. This could include mandates and incentives. What were the	In order to help customer for business transformation, the lead consultant and software company provided standard training programs for customers and partners in this project to let them understand and make full use of the platform. For Singapore project, customers can access to demo centers and experience centers around the world, enabling them to get experience on the solution platform.

organisational change experiences of gaining acceptance and adoption of the platforms by the user communities?	
Training / publicity Identification of the types and levels of publicity and training to promote the adoption of the platform and platform services.	Standard training program for department/Agency, Partner, and customers were setup to enable the knowledge transferring. Singapore appointed a department as a transformation driver and assigned resources to be trained. Trainers follow a standardised program (train the trainer) and perform training for each organisation.

Table 2.1 – Best Practice and Lessons Learnt from Singapore's CSDI and BEAP

2.4.1.7 The strengths, weaknesses, opportunities and threats (SWOT) analysis from the Virtual Singapore case study is shown in **Table 2.2**.

Strengths	• **Application-focused with data as an enabling factor**: The Virtual Singapore project pay a lot of attention to see how the collected data and the platform to serve future applications in planning and development. Strategically, the data collected in the first phase is to align with and facilitate the application development plan. At the second phase of the project, their ultimate goal is to trigger various departments to harness the collected and collated data to further trigger new applications and provide new services and functions through the platform. • **Clear target from National level**: Virtual Singapore project is an instrument of the "Smart Nation" strategy in Singapore to ensure applicability of concepts on the city virtual twin. The country where Singapore locate in has good ICT infrastructure, leading IT company, IT/IoT/AI human resources and business environment to keep sustainable smart city development. • **Business and operation model**: "Virtual Singapore" is funded by National fund organisation. The government has encouraged different departments and non-government organisations such as university and enterprises to use this Virtual Singapore platform for smart nation/city research and application development. • **"Single source of the truth" data**: The Virtual Singapore project has adopted a fresh new concept "Single source of the truth" for data processing. Compared with traditional central data management concept, which are rather complicated and need data update/processing regularly, this project uses the RESTful API for data retrieval and displays the data on the platform using widget technology. The platform serves as a single point of access for content and applications originating from several sources, in multiple formats. The content can be real-time, proprietary, open and up-to-date from its originating source.

	• **Security and privacy safeguards**: This project will create a dynamic, 3D digital model of Singapore and connect all stakeholders in a secured and controlled environment. It enables public agencies, academia and the research community, the private sector, and also the community to make use of the information and system capabilities for policy and business analysis, decision making, test-bedding of ideas, community collaboration. • **Strong support for collaboration & public engagement**: With data from various public agencies, including geometric, geospatial and topology, as well as legacy and real-time data such as demographics, movement or climate, this project supports the collaboration between and within departments such as Land Authority, Administration of Transportation, Urban planning, etc. And the cloud-based solution provided citizens with a virtual yet realistic platform to connect, create awareness and services that enrich their community. • **Support of partner development**: Based on this one unique virtual environment, the 3D city model with semantic information accessible by different departments. This project provides ample opportunities for researchers to develop advanced 3D applications and tools. Partners can develop web based applications for viewers, leveraging the security, "Single source of the truth" data, and the collaborative tools provided by the platform.
Weakness	• **No standardisation in IoT**: The project did not include a common standardised definition for IoT field, making it more complex when interfacing with IoT devices. • **Complexity of source data**: To setup the 3D model, because of the variety of different kind of source data format in this area, the original data need to be checked and processed before loading into the platform.
Opportunities	• **Smart city business model**: Develop advanced smart city business model, technologies and human resources, smart city become a new economy growth engine for Singapore. With this smart city business model, Singapore will have even better living and business environment to attract high end human resource, investment and global enterprises to set up their headquarters in the region. Also, to outsource smart city technology and related services to other country would also be a potential economy growth engine. • **Expansion of underground 3D application**: Singapore has reached its horizontal expansion and is now seeking for new opportunities to develop its urban areas underground and on shore. 3D contributes to support decision making with 3D visual, KPI and simulation for each alternatives. It offers a unified collaborative environment for the Cities, natively supporting standard as BIM and GIS. The new applications developed based on this platform can make full use of the collaboration, BIM and GIS technology. • **High-Tech led applications development**: By developing smart city technology, Singapore will incorporate new technologies such as AI, Cloud, Industry 4.0 and so on into the platform to develop new applications, tools/products through cloud computing, big data analytics, machine learning, etc.
Threats	• **Digitalisation & data collection**: Digitalisation cannot be provided by one single provider and must be collected by various domains (urban furniture,

	construction, utilities). City project users must take into account different kind of situations, for example, cars collected data in Singapore cannot enter into some area in central city, must use a pedestrian for data collection.

Table 2.2 – SWOT Analysis of Virtual Singapore Case Study

2.4.2 AURIN – Australia

2.4.2.1 Established in June 2010, the Australian Urban Research Infrastructure Network (AURIN) is an initiative of the Australian Government under the National Collaborative Research Infrastructure Strategy (NCRIS) and associated programmes. AURIN is a collaborative network of leading researchers and data providers across the academic, government, and private sectors that provides:

- a one-stop online portal with more than 3,500 multi-disciplinary datasets, from over 98 different data sources (the AURIN Portal); and
- a suite of additional open-source tools and applications, covering spatial and statistical modelling, planning and visualization (the AURIN Workbench). AURIN aims to provide urban and built environment researchers with access to diverse sources of data, data integration capabilities, and an e-research capability for interrogating those data.

2.4.2.2 Funded by the Australian Government through the Education Investment Fund and the NCRIS, the $24 million AURIN initiative is building the e-research infrastructure to enable better understanding of the current state of Australia's cities and towns and to meet the challenges they are facing. AURIN enables Australian planners and researchers to make informed decisions about future infrastructures and urban environments based on realistic scenarios and evidence-based analysis. **Table 2.3** presents the overview of AURIN built environment application platform.

BUSINESS ARCHITECTURE *The Business Architecture view looks at the corporate aspects of the platform such as how it fits within the organisation, the services and products it provides and how it operates.*	
Business services provided by the BEAP A description of the business services and products provided by the unit/organisation such as: spatial data provision, data brokerage, analysis, software provision/sales, user training, etc. Who is the target audience for the BEAP?	AURIN is a collaborative network of leading researchers and data providers across the academic, government, and private sectors, which provides: • a one-stop online portal with more than 3,500 multi-disciplinary datasets, from over 98 different data sources (the AURIN Portal); and • a suite of additional open-source tools and applications, covering spatial and statistical modelling, planning and visualization (the AURIN Workbench). AURIN aims to provide urban and built environment researchers with access to diverse sources of data, data integration capabilities, and an e-research capability for interrogating those data. Using the above, AURIN enables Australian planners and researchers to make informed decisions about future infrastructure and urban environments based on realistic scenarios and evidence-based analysis. In addition to the above, AURIN also provides a mapping portal with limited functionality and datasets to the general public at: https://map.aurin.org.au/
Legislation, policies and procedures Are there any	In July 2010 the Australian government released a Declaration of Open Government to promote an open government based on 'better access to and use of government held information, and sustained by the innovative use of technology' (Australian

specific legislation, statutory instruments, guidance, policies or procedures in place to facilitate the platform?	Government, 2010). This legislated approach to open data is essential for AURIN to deliver its services. One of the primary benefits behind this open government initiative is the broad scale release of government information, including many data sets held by both Commonwealth and State Government bodies. To distribute this information, the Australian Commonwealth Department of Finance and Deregulation has established that Australian Data Hub (http://data.gov.au/), a broad scale data hub for discovery and access to government data based on the OKF CKAN platform (OKF, 2013A). The principal aim of data.gov.au is to support the discovery and publishing of public sector information for public access, better reuse across the whole of government, and to support openness, transparency and economic development in the Australian community. This aim is supported by numerous government policies listed below, which encourage agencies to publish government datasets on or linked through data.gov.au: Public Data Policy Statement: Department of the Prime Minister and Cabinet. December 7, 2015 http://www.dpmc.gov.au/pmc/about-pmc/core-priorities/public-data-branch-within-dpmc/public-data-policy-statement Open public sector information: from principles to practice (OAIC). February 2013 http://www.oaic.gov.au/information-policy/information-policy-resources/information-policy-reports/open-public-sector-information-from-principles-to-practice Australian Privacy Principles (APPs) Guidelines (OAIC) https://www.oaic.gov.au/agencies-and-organisations/app-guidelines/ Chapter 2: APP 2 — Anonymity and pseudonymity https://www.oaic.gov.au/agencies-and-organisations/app-guidelines/chapter-2-app-2-anonymity-and-pseudonymity One ANZ Foundation Spatial Data Framework – Project Implementation Plan (OSP). November 2012 http://spatial.gov.au/anzlic/one-anz-foundation-spatial-data-framework-project-implementation-plan The Australian Public Service ICT Strategy 2012-2015 (Finance). October 2012 http://www.finance.gov.au/policy-guides-procurement/ict_strategy_2012_2015/ Digital Transition Policy (National Archives of Australia). March 2011 http://www.naa.gov.au/records-management/digital-transition-policy/ The Australian Government Web Guide (Finance). Updated regularly http://webguide.gov.au/ which includes: Publishing Public Sector Information. February 2012 http://webguide.gov.au/web-2-0/publishing-public-sector-information/ Web Accessibility Policy. April 2011 http://webguide.gov.au/accessibility-usability/accessibility/ Statement of Intellectual Property Principles for Australian Government (AGD). October 2010 http://www.ag.gov.au/RightsAndProtections/IntellectualProperty/Documents/StatementofIPprinciplesforAusGovagencies.pdf Declaration of Open Government (Finance). July 2010 http://www.finance.gov.au/blog/2010/07/16/declaration-open-government/ Web Accessibility National Transition Strategy (Finance). June 2010 http://www.finance.gov.au/publications/wcag-2-implementation/ Government Response to the Gov 2.0 Taskforce Report (Finance). May 2010 http://www.finance.gov.au/publications/govresponse20report/doc/Government-Response-to-Gov-2-0-Report.pdf

	Ahead of the Game – Blueprint for the Reform of Australian Government Administration (PM&C). March 2010 http://www.dpmc.gov.au/publications/aga_reform/aga_reform_blueprint/index.cfm
Performance management / KPIs How does the unit/ organisation measure its performance against targets and what key performance indicators does it use for each of its services / functions.	As a research project primarily funded by the Australian Government through the National Research Infrastructure for Australia (NRIA), AURIN is subject to audit from the NRIA. At the time of writing we have not found any specific KPIs relating to the measurement of AURIN's services, nor the methodology or tools that might be used to measure success.
Governance / institutional arrangements How does the unit/ organisation fit within the organisation (or is it an independent organisation) and what governance arrangements are in place?	AURIN is a collaborative research project, which for funding, administrative and legal purposes, falls within the remit of the University of Melbourne. The University of Melbourne (School of Engineering), as AURIN's lead agent, administers, operates and controls AURIN. AURIN is overseen by a Management Board which provides strategic oversight for the AURIN Project, comprising members of the urban research community in Australia, including the following roles (at the time of writing): • Director, AURIN • Research Professor in Sustainable Urbanism, Swinburne University of Technology • Director, City Futures Research Centre, Built Environment, University of New South Wales • Pro Vice-Chancellor (Research Collaboration and Infrastructure), The University of Melbourne • An independent specialist Consultant The reporting pathways of the board are not known (i.e. to whom does the board report and to whom is it accountable?).
Staffing / resourcing Does the unit/ organisation have dedicated staff; how many people are involved and what roles do they have?	AURIN has a dedicated staff team comprising the following roles (around 15-20 in total): Project Directorate Director Project Administration Assistant Data Team Deputy Director Data Relationships Manager Data Lead Systems Admin/Project Manager Geospatial Data Officer (QCIF) Data Officer Outreach Manager Technical Team Director, eResearch Technical/Implementation Project Manager Data Architect Senior Software Developer Systems Admin/Developer User Interface Software Engineer
Funding model How was the development funded	Funding for AURIN has been provided through grants by the Australian Government under the Education Investment Fund and the National Collaborative Research Infrastructure Strategy (NCRIS) and associated programmes. From establishment in

and how is its operation funded? How are individual products and services charged for? Is the business case for the establishment of the platform available? What are the on-going costs of operating the platform?	2010 to date, funding of AUD$24 million has been received for the establishment and ongoing operation of AURIN.
Usage agreements and licensing What service agreements and/or licensing is used when accessing the services and data? Are there Service Level Agreements in place for the provision of the platform services?	Creative Commons Licence To the maximum extent possible, the datasets provided via the AURIN Portal and their contents, to the extent they are protected by copyright, are provided under a Creative Commons licence. The metadata record associated with the dataset indicates whether a Creative Commons Licence applies, and will provide a link to the relevant licence (e.g. Creative Commons Attribution-Noncommercial 4.0 International (CC BY-NC 4.0)) Other licence types To make a range of data available to researchers, AURIN obtains some data through agreement with commercial and government data providers. In some cases, these datasets are provided with specific terms and conditions for end users (what AURIN refers to as the Data Terms & Conditions). Where this is the case, a pop-up will appear directing the user to read and agree to the Data Terms & Conditions before using the dataset. Any Data Terms & Conditions are also included in the dataset's metadata record. Terms of Use AURIN publish terms of use for the service at: https://aurin.org.au/compliance/aurin-terms-of-use/ In keeping with the spirit of open access, the T's & C's are not onerous: "We grant you a licence to access the AURIN Site and to use AURIN Data and AURIN E-tools, subject to these terms of use. You may use, reproduce, publish, communicate or adapt AURIN Data that you access in the course of your use of the AURIN Site. You may use AURIN E-tools to interrogate and model AURIN Data." Users are expected to appropriately attribute the data sources, instructions for which are provided. Any commercial use of the AURIN Site, AURIN Data or AURIN E-tools is strictly prohibited, where 'commercial use' is one intended for commercial advantage or to obtain financial compensation. AURIN provides its service (including the data) on an 'as is' basis, i.e. they do not guarantee the currency or accuracy of the data, nor do they provide any guarantees of system uptime or performance. "Unless otherwise agreed in writing, software distributed under the License is distributed on an "AS IS" BASIS, WITHOUT WARRANTIES OR CONDITIONS OF ANY KIND, either express or implied. See the License for the specific language governing permissions and limitations under the License." "We do not warrant that AURIN Data is accurate, complete or up-to-date, or that its use will not infringe any third party rights. AURIN Data comes from a number of third party data providers and those data providers are responsible for their particular datasets. Your use of AURIN Data is at your own risk. You should check the accuracy, completeness and currency of any dataset with the relevant data provider before relying on it. Please notify us if you think any AURIN Data is inaccurate, incomplete, unreliable or out of date by emailing data@aurin.org.au."

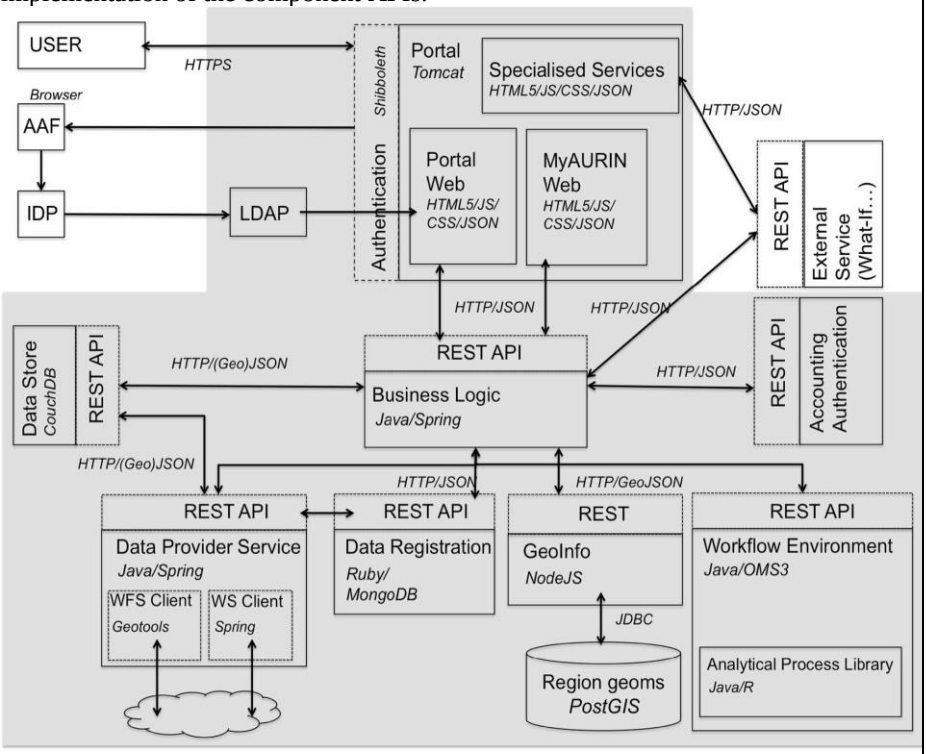
APPLICATION ARCHITECTURE

The Application Architecture view considers how the suite of applications work together to provide the business services described above, as well as the supporting 'back office' applications required to deliver those services. This view is not concerned with any single end user application but rather on how the platform is constructed.

System architecture / technical building blocks
Describes the major components of the platform infrastructure and how it relates to other systems such as an underlying Spatial Data Infrastructure (SDI). This section should also consider licensing models/costs in cases where proprietary software is used within the platform.

Technical Architecture

The AURIN Technical Architecture follows a client-server, service-oriented (or resource-oriented) architecture model applied in a fashion that maximises re-use, scalability, and independence of its individual components. The aim is to establish a loosely coupled, flexible and extensible service-based architecture. Key to this architecture is that individual functional components can be reused in different situations. The implementation details of each component are hidden as much as possible from the external applications and end users. The design of each component allows for use of different programming languages and for their deployment on different operating systems. Key to this is the consistent specification and implementation of the component APIs.



Individual components communicate through Web Service API calls, applying the Representational State Transfer (REST)-ful style of Web services. REST is a particularly useful style of encoding resources within a Web environment, where URLs (Uniform Resource Locators) act as the interface to resources (components). The syntax of the URLs is human readable and eases the complexity of development against REST services considerably.

The AURIN e-Infrastructure leverages JavaScript Object Notation (JSON – json.org) – a lightweight message format, for the encoding of the majority of its communication. JSON allows for hybrid messages with adaptive content. This is particularly advantageous for the complex data descriptions and formats to be passed around within the AURIN e-Infrastructure. The GeoJSON extension of JSON (www.geojson.org) in particular has been adopted for internal spatial data transfers. The overview of the internal architecture of AURIN is shown in the figure above.

	Software The AURIN Portal and web tools have been developed using open source tools, principally CKAN, which is a tool for making open data websites. CKAN describe it as follows: "Think of a content management system like WordPress - but for data, instead of pages and blog posts. It helps you manage and publish collections of data. It is used by national and local governments, research institutions, and other organisations who collect a lot of data." For more information, see: http://docs.ckan.org/en/ckan-2.6.0/contents.html AURIN Map uses TerrisJS technology available as a Github project (https://github.com/AURIN/nationalmap). The TerriaJS software was initially developed by NICTA for National Map, and has subsequently been used for other projects. AURIN Map core software is licenced under the Apache licence, Version 2.0. (https://www.apache.org/licenses/LICENSE-2.0). **Additional Open Source Software Used** In developing AURIN Map, AURIN has used open source software and contributed back to it. AURIN Map leverages these excellent open source libraries: • TerriaJS • Cesium • Leaflet The complete list is available with the National Map source code.
Applications deployed Describes both the core application components of the platform itself, as well as identifying some of the end-user applications that are supported by the platform. Does the platform present Read-Only data or does it support data creation and update as well?	**AURIN WORKBENCH** The AURIN Workbench is a web-based suite of data discovery, visualization and analytical tools that are available to the registered users of AURIN. The Workbench is free to use for all staff working at, or enrolled in a university in Australia. It is also free to use for all employees of government departments, across all sectors and levels in Australia. Members of the public or other organisations (e.g. charities and private sector) cannot access the Workbench. A more limited set of data are available via the publicly-accessible AURIN Map site (see below). **Mapping and analytics** AURIN Portal The AURIN Portal is AURIN's flagship workbench tool, bringing together thousands of authoritative, spatially-enabled datasets into a single, robust online analytical platform. The Portal is the ideal tool for researchers, policy makers, and educators alike to answer the important questions about the sustainable and productive futures of Australia's towns and cities. **Data discovery** AURIN Data Discovery Tool is a Metadata Catalogue. Users can browse the growing list of datasets accessible through the AURIN Portal and AURIN Open API. There are now over 3,000 datasets from almost 100 sources, covering a wide range of disciplines. Users can search by keyword, organisation, geographic boundaries, or licensing type, allowing them to quickly determine the kinds of data available in AURIN that are fit for their work. With AURIN's unique federated system, the data stays with the data custodian. This allows researchers to browse the data before accessing or downloading custom datasets. This also provides seamless access to data as it is updated and maintained at its source. The Data Discovery Tool is supported by an open Metadata Management System. **Decision Support** WhatIf? Planning Support Tool. The future of urban planning. Scenarios to help target investment and job creation. ENVISION Planning Support Tool. Multi-criteria evaluation and strategic, map-based, precinct-level planning.

	ENVISION Scenario Planning Tool (ESP). Populate, manipulate and analyse in 3D precincts identified in ENVISION. Economic Impact Analysis Tool. Economic input/output analysis for all LGAs across Australia. Housemod. Micro-simulation model of housing policy and affordability in Australia and its regions. **Volumetric Modelling Tools** • AURIN 3D Volumetric Module • AURIN-Australian Stocks and Flows (ASFF) **AURIN MAP** Public mapping portal: 'AURIN Map'. Statistical and Analytical tools and Visualizations for Urban Research Data.
Support for collaboration and public engagement The focus we are particularly interested in how other platforms have enabled collaboration between departments, public sector, academia and the public.	Led by The University of Melbourne, AURIN collaborates with more than 60 institutions and data providers across the academic, government, and private sectors in Australia through contracted subprojects and Data Access Agreements. AURIN, through its Portal (and Workbench), in turn supports more than 7,400 registered academic and government users. The AURIN Map facility is publicly available to any user who agrees to the terms of use, and users can upload their own data to the AURIN map to visualize their data against that available through AURIN. A similar, though much-enhanced facility exists for the AURIN Portal users. AURIN's focus on Open Data and Open Platform, through applying internationally-adopted open standards, and its role as a 'hub of hubs', means that it can fulfil the role of national one-stop-shop for data and analytical tools for the built environment and urban planning in Australia.
Application Programming Interfaces (APIs) provided How are the services of the platform exposed to support end-user application development and what APIs and languages are supported?	AURIN has developed an Application Programming Interface (API) to allow users to access a whole range of open datasets, without having to log in to the portal. Users can access these datasets via desktop GIS programs such as QGIS, mobile apps, and other programming or technical environments and platforms (such as R, Jupyter). AURIN Open API: AURIN supports open data. Datasets available through the Open API are licensed under Creative Commons licences and can be used for purposes including commercial ones. AURIN Non Commercial API: AURIN has created a non-commercial API following demand from users for access to AURIN datasets. Datasets available through the Non Commercial API are licensed under Creative Commons Non-Commercial licences. This means that data contributors chose to licence their data for non-commercial use. AURIN supports the right of contributors to choose how to licence their data. A list of datasets available through the AURIN Non-Commercial API can be found at: https://aurin.org.au/aurin-apis/datasets-available-in-the-openapi/ Users must register to use the AURIN Open API. AURIN requires the applicant complete a registration form and agree to AURIN's Non-Commercial API Terms of Use. If you do not accept the Terms, you may not use the AURIN Non-Commercial API. AURIN User Community: AURIN is keen to build a user community around the Non-Commercial API. This will help AURIN understand the demand for different datasets in the wider Australian community and identify what datasets may benefit the broader community. Applicants who wish to use the AURIN API are invited to participate in this community during the registration process. Communication with the community includes a quarterly newsletter issued by AURIN.
Channels	AURIN provides its services and data via the internet through its two portals:

Through what mechanisms can users and applications interact e.g. web, mobile app, desktop application, face to face service desk, kiosks, custom devices, etc.?	www.portal.aurin.org.au (full suite of tools and data available to registered research and government users) www.map.aurin.org.au (limited web mapping tool and limited data available to general public) It also publishes an AURIN API which registered users can use to access data and tools directly.
Interoperability, use of standards What technical standards have been adopted to enable a broad range of technologies to interact with the platform?	AURIN have adopted the Open Geospatial Consortium standards.
Security How have security mechanisms been implemented to protect the platform and to authenticate users and manage access privileges?	**Access and authentication** Most of the facilities delivered through the AURIN Workbench are securely password protected and not accessible by the general public. The Portal Access to the Portal is restricted by login and password and all users of this facility have to agree to the Terms of Use. Broadly, end users fall into two categories: *Researchers:* These users are primarily university staff and students undertaking analysis of environmental, social and economic processes in urban Australia. Generally, these users are members of organisations already registered with the Australian Access Federation (AAF, a national service which provides federated authentication for research users of information infrastructure at Australian universities and other research institutions such as the CSIRO. AAF members can login to the AURIN Portal using their university email addresses and passwords. *Policy and decision-makers:* These users are comprised primarily of staff from local, state and federal governments who are focused on using data and analytical tools to support public policy and management. These users apply to AURIN individually for an account to access the AURIN Portal, using the AAF 'Virtual Home Organisation' mechanism. When providing data to AURIN, a data provider can release data to both user groups, or may choose to release it only to researchers. For certain types of data, such as data containing commercially sensitive information, AURIN can discuss additional options to restrict use. AURIN can facilitate technical discussions to explore appropriate data release options. *Other Workbench facilities and tools:* Access to other AURIN facilities is supplied on request to and approval by the AURIN office. Some AURIN facilities have open access where there is no need for restricted access to the underlying data. **Data Security** AURIN takes reasonable steps to keep data secure through the AURIN environment. AURIN ensures appropriate levels in the following ways: Access to the AURIN Portal is restricted to AURIN end users (as explained above). Data providers are encouraged to store data on their own infrastructure and to deliver it dynamically through the Portal. This helps to maintain the currency of the data. It

	also means that data providers can autonomously manage their own security arrangements. Most of the data available on the Portal is stored in this way. Where possible, AURIN use 'pull-based' query mechanisms to ensure that direct incoming connections from the internet to a data provider's systems are not required. Data that is held on AURIN infrastructure is kept on secure servers and delivered through secure SSL connections. Data storage and security arrangements for particular datasets are not visible to end users, who access the Portal only through a single sign-on to the application interface. Of course, no security system is impenetrable and due to the inherent nature of the internet, AURIN cannot guarantee that information, during transmission through the internet or stored on our servers, will be absolutely safe from unauthorised access by others. **Data Breaches and Unauthorised Use** AURIN takes steps to secure the information it collects from misuse, interference and loss, and from unauthorised access, modification or disclosure. A data breach occurs when the information collected and stored by AURIN is misused or is removed, accessed or disclosed without permission. Users report a data breach by emailing the AURIN Data Officer.
Platform monitoring and administrative functionality What functionality has been implemented within the platform to monitor service provision and system health, as well as to support administrative tasks such as usage throttling, fee collection, adding new services and updating existing services?	Not disclosed by AURIN
DATA ARCHITECTURE *The Data Architecture view considers how the data is organised and how the appropriate data is presented to end users and systems. We are interested in the relationship between the application platform and the Spatial Data Infrastructure and thus (if relevant) the data view should consider the distinction between raw/source data from business systems, etc, and the data that is presented to the platform end-user applications. In those cases where the platform is responsible for presenting tailored information products by processing source data sets then the products and production process should be described where possible.*	
Information products / data enrichment Identification of the information products that are presented by the platform as well as describing any	AURIN covers disciplines including demography, property and housing, transport, health, energy and water, master planning. AURIN does not appear to process data to create enriched information products. Although AURIN does some data in local data hubs, its preferred model is to act as a portal that directs users to access published data from the source data providers in a federated fashion.

processing and enrichment of source data to produce a data product that is re-purposed / tailored for built environment applications.	
Data access rights and agreements This section identifies the types of data agreements between the data providers and the platform provider.	AURIN's preferred method of data licensing is through the Creative Commons 4.0 framework. However, AURIN realise that this framework does not suit all data products or organisations. As such, AURIN has worked together with data providers and legal counsel to develop the AURIN Standard Data Licence. The AURIN Standard Data Licence is designed to meet data providers' requirements, while also allowing for the unique data facilitation role provided by AURIN. AURIN may also consider specific terms for providers of health data or other data providers with particular privacy or data protection needs. For further information on licensing, please refer to AURIN's Licensing Factsheet and to AURIN's Data Licence FAQs page.
Data sources, formats and management When relevant, identify where source data has come from and how it has been exposed to the application platform.	AURIN's data is sourced from across Australia, from research institutions, government and private enterprise. The process for providing data through AURIN can be broken down in to five stages: identification, licensing, processing, publication and feedback. Each of these stages is briefly described below: **Identification** AURIN works together with expert groups of end users and Sub-Project Partners to identify useful datasets for urban research. AURIN communicate with relevant data providers, and AURIN facilitates a negotiation process to determine the most appropriate data to meet the expectations of both the data providers and the end users. **Licensing** (See above) **Processing** AURIN believes that most data is already fit to be integrated into the AURIN Portal, though some processing may be required to ensure the data can be accessed, analysed and visualized. In addition, AURIN requires a minimum standard of metadata be created for each dataset, including descriptions for individual dataset attributes. This is to ensure that end users who are unfamiliar with a particular dataset have the most information available to determine if a dataset is fit for their purposes. **Publication** An appropriate data feed is required to allow users to access data in the AURIN Portal. The optimal solution is for data to be held and accessed directly from data providers. This may increase end users' confidence that they are accessing authoritative versions of datasets. If a data provider does not have the technical facilities to allow this access, AURIN has a number of Data Hubs established around Australia to allow data providers to contribute their data and make it available to the AURIN portal. **Feedback** Once data is being used within the AURIN Portal, a data provider can receive various types of metrics from AURIN and the AURIN end users, such as data usage statistics, data quality feedback and examples of how the data is being used in research projects. This feedback can be used to inform data and business investment decisions in the future.
Foundation datasets, reference geographies	This is an enormous list (3,500 datasets). To browse the available datasets, please see: https://data.aurin.org.au/dataset

Identification of the fundamental reference datasets that are used to register other datasets; this could include administrative areas, statistical units, official name gazetteers, etc.	
Data quality assessment / suitability assessment Describes if / how data quality assessments are conducted prior to serving data via the application platform. This could also include consideration for how platform users might assess the suitability of a dataset or service for their particular use.	Apart from the information already provided elsewhere in this table, no further detail on how datasets are assessed prior to their being made available on the AURIN platform has been found.
Support for personal privacy Describes the steps taken to protect personal privacy, particularly when generating information products from several data sources where there is a risk of exposing personal information through data aggregation.	The data made available through the AURIN Portal is commonly aggregated or anonymised such that it does not contain any personal information. For example, where datasets may have contained health information about identifiable individuals or fine-grained demographic information, AURIN has worked with data providers to aggregate, anonymise or withhold this information. AURIN collects, holds, uses and discloses personal information in accordance with its Privacy Policy (accessed at: https://aurin.org.au/compliance/privacy-policy/)
Data model standards Identification of the use of any published data models and lessons learnt from the ways data in which data is presented or described. If the platform supports data creation and data updates then how is this managed	By adopting the Statistical Data and Metadata Exchange (SMDX) format, more than 500 socio-economic data products can be dynamically searched, browsed, accessed and analysed via the AURIN portal. The significance of this approach is that urban geographers can access both the datasets and statistical analysis tools via the same online Portal and thus in theory, conduct their research more efficiently.

and where is the data stored?	
TECHNICAL ARCHITECTURE *The Technical Architecture view considers the physical IT infrastructure elements such as the servers and networks that host the platform. Whilst much of this detail is of limited interest in this desktop study, we are interested in general trends that may be relevant to the development of the BEAP.*	
Cloud hosted vs on premise Describes how the application platform is physically hosted, in particular which elements may be cloud hosted and the rationale for that.	The AURIN applications and databases are hosted on premise on four main servers. This includes two database servers and two compute servers (each offering 256 Gb memory and over 20 TB storage) which run multiple virtual machines [1]. This infrastructure is hosted and managed by the AURIN team at the University of Melbourne[2]. Prototyping of systems utilizes Cloud-based resources offered through the Australian National eResearch Collaboration Tools and Resources project (NeCTAR – www.nectar.org.au).
IMPLEMENTATION AND USER CONVERSION *What lessons can be learnt about implementation and user conversion aspects of the case study platforms?*	
Implementation process and phases Identification of the history of platform development / evolution and the business drivers of each stage	See the AURIN Final Project Plan (available from: https://aurin.org.au/wp-content/uploads/2014/07/AURIN_Final_Project_Plan.pdf) for full details on the implementation of the platform. Funding for the creation of AURIN was agreed in 2009, with the project formally commencing in mid-2010. The implementation of the AURIN e-Infrastructure commenced mid-2011, with the first year of the project focused largely on gathering community-wide research requirements on the core capabilities and data sets that should be provisioned (made accessible) through the e-Infrastructure to the urban and built environment research community. The University of Melbourne was (and remains) the lead agent responsible for the successful delivery of the AURIN e-Infrastructure, but the project is being developed and delivered in a networked manner – working with a multitude of agencies and groups across Australia providing either data or tools that should be integrated into the AURIN e-Infrastructure. The Melbourne eResearch Group at the University of Melbourne are primarily tasked with this integration effort.
Uptake / change management Identification of any specific actions that were taken to encourage the adoption of the platform and their success. This could include mandates and incentives. What were the organisational change experiences of gaining	Unknown

[1] https://lungfoundation.com.au/wp-content/uploads/2016/02/The-Australia-urban-research-gateway.pdf

[2] https://minerva-access.unimelb.edu.au/bitstream/handle/11343/32714/287043_SINNOTT_Tools%20and%20processes_cpaper.pdf

acceptance and adoption of the platforms by the user communities?	
Training / publicity Identification of the types and levels of publicity and training to promote the adoption of the platform and platform services.	AURIN provides comprehensive information on the use of the platform, its tools and applications at: https://aurin.org.au/docs/ This includes documents, tutorials and videos. AURIN also has a blog and news page, but neither contain much information. Most of the promotion of the platform appears to be through academic and research channels (e.g. appearance at conferences and events, numerous research publications).

Table 2.3 – Overview of AURIN BEAP

2.4.2.22 The SWOT analysis from the AURIN case study is shown in **Table 2.4**.

Strengths	• AURIN provides a **window into a large array of data that was previously hidden** behind organisational firewalls and legal frameworks. Researchers typically used to spend weeks or even months finding relevant data (even learning if it existed in the first place). AURIN has made these data visible through data discovery tools such as the AURIN Portal application and Data Discovery Tool. The Portal allows **researchers to visualize the data and determine whether it will serve their purposes to develop various applications and tools**.3 This approach fosters the creation of more applications by academics and industry professionals in order to maximise utilisation of the new wealth of data now available. • AURIN **acts as a 'data broker'** for its users by managing the usage agreements and licences so that users don't have to negotiate on an individual basis with the data owners. These pre-agreed usage and licence agreements follow open data standards wherever possible, and define clearly how and where the data can be used. • AURIN has adopted a **federated data model**, where responsibility for data ownership and quality lie with owner/custodian (not AURIN). Therefore, there is no need for complicated agreements and arrangements regarding data ownership and maintenance; rather, ownership and responsibility for data currency and quality remains with the originating organisation. This federated model is essential for many reasons: For many datasets, e.g. individual unit records or data from commercial organisations, it is simply not tenable to build a centralised data warehouse for all urban data. Furthermore, as data grows and evolves over time it is highly beneficial to seamlessly leverage these updates and enhancements from the originating source rather than maintain a copy of that data in central hub. Federated data access models provide such opportunities in a multi-agency environment that a centralised data warehouse does not. • In recognition of the diverse and often siloed political structures of Australia and the desire for the organisations to maintain control of their data and their desire to have their own systems that suit their own needs, AURIN does not mandate that that complex AURIN-specific software systems/software stacks are installed and configured on government/commercial enterprise resources. Rather the

[3] Sinnott, R. et al (2013) 'The Urban Research Gateway for Australia: Development of a Federated, Multi-disciplinary Research e-Infrastructure.' Paper presented at the 5th International Workshop on Science Gateways, Zurich, Switzerland.

AURIN e-Infrastructure has been **designed to be cognisant of the existing solutions already deployed by the organisations involved**.

- AURIN has **developed an API to allow users to access a whole range of open datasets**, without having to log in to the portal. Users can access these datasets directly via desktop GIS programs such as QGIS, mobile apps, and other programming or technical environments and platforms (such as R, Jupyter). The AURIN APIs contain data contributed to AURIN as part of activities to enhance research outcomes and knowledge about cities, regions and urban infrastructure. The availability of the APIs help drive and develop applications to visualize, understand and analyse the large array of data.
- AURIN has **adopted an ethos of Open Source data and software** throughout, intentionally avoiding bespoke and proprietary systems and approaches. Whilst AURIN's applications are of course bespoke, they have been written using open source principles and the source code is published openly.
- AURIN has **adopted open GIS and international spatial data standards** to maximise interoperability.
- AURIN **recognises the importance of employing a dedicated team** of spatial information specialists to manage and develop the platform. This ensures that the platform is properly resourced to ensure consistent and reliable operation.
- AURIN's applications such as AURIN Map and Portal are user-friendly applications that display the dataset requested in order to provide contextual and location-specific information to the end user. These interlinked tools are not only useful for visualizing different government data, they also allow users to **superimpose their own data** in order to spur innovative test cases and extrapolate information from overlapping custom data with public data.
- The provision of a highly accessible web-based application allows a wide group of users to visualize the built environment in a new way. The ability to customise and present selective data juxtaposed with one another provides as a **catalyst for innovative data analytics** that would not have been possible with the raw data alone.
- AURIN Map is highly accessible as it is a **web-based application**, and is not reliant on the computing power of the end user. An added benefit is the ability to share and/or embed the map into an HTML page.
- AURIN Portal provides more control to the user than the publicly accessible AURIN Map. In addition to visualization tools, the application provides users data manipulation, indices, migration analysis, statistical analysis and other tools. Users are able to plot charts from the data, and observe meaningful trends, identify unique relationships and generate insightful conclusions from the wealth of information available on the AURIN database.
- AURIN's WhatIf? Planning Support tool is another online application that enhances and supports collaborative planning. The application allows users to create scenarios for determining the suitability of land, projecting the demand for land, and projecting future land use, population and employment patterns. The outputs are in the form of maps and reports that can be customised to reflect a community's concerns and desires, taking into account policy choices to prepare long-term projections.

	• AURIN's ENVISION application translates the social, economic and spatial data into a set of indicators that can help identify areas for redevelopment. The application focuses on having the user identify and weigh different variables in order to generate the most suitable outcome based on the significance criteria established by the user. • AURIN's Envision Scenario Planner tool is the most robust application currently available. The web-based application allows planners to design, visualize and assess the **performance of a whole precinct** by applying the data in the AURIN database to custom scenarios. The application will also report on a wide range of performance categories from resource management to financial impact. • AURIN's applications provide platforms which consolidate the raw data allowing planners and other users to model the built environment in a new and efficient way. Previously inaccessible data is now incorporated directly into simulations and the applications can afford users limitless possibilities for analysis. The hypothetical scenarios can be evaluated in a much more expedited process, and enables a wide variety of conclusions to be drawn in a matter of minutes.
Weakness	• The platform is more for research purpose and government use. The involvement of private sector and industry is relatively week comparing to Virtual Singapore. A business model is yet to develop, and the strategy of **turning research outputs to applications/products** can be further strengthen. • The corollary of a federated model is that **AURIN is dependent on its data owners and custodians to maintain the quality and currency of their data**. Whilst AURIN can monitor quality and veracity, it ultimately falls to the data provider to ensure that its data remains suitable for the uses that the AURIN licences and agreements state. • Equally, AURIN is dependent upon the data providers to **maintain their infrastructure and the data feed out to AURIN**. Failure of a data connection means that the data is no longer available to users via the AURIN platform, either permanently or temporarily. • The full set of urban data made available through the AURIN portal is **not accessible to all** – only registered government and educational users may access this data and the analytical tools and applications provided via the AURIN Workbench. A much-reduced set of data is available to public users via the AURIN Map application. • AURIN state that one of the major challenges to the development and operation of AURIN and distributed networks such as AURIN is not the distributed ICT systems and hardware resources, but **finding an effective means of collaboration for the distributed teams of people** who are involved in developing and managing the platform and it very dispersed collection of datasets. In AURIN's experience, the methods and tools available to optimise the way in which these people can coordinate their activities "are essential yet are surprisingly not well recognised and adopted." 4

[4] Sinnott, R. et al (2013) 'Tools and Processes to Support the Development of a National Platform for Urban Research: Lessons (Being) Learnt from the AURIN Project.' Paper published in Conferences in Research and Practice in Information Technology Series, 2013, 140 pp. 39 - 48.

Opportunities	• There is potential **for the AURIN toolset to grow** as researchers **develop new applications for urban data analysis and modelling**. This is supported by AURIN's open approach to publishing its API. Provision of an increasing suite of useful tools to support urban and built environment research and planning will further embed AURIN's place as an essential platform in this area of study.
Threats	• Perhaps the principal threat to AURIN is its **funding model**. AURIN is reliant on ongoing government funding primarily through education grants schemes, whereas industry and enterprise funding has yet to be involved. It is unclear where future funding will come from, although the University of Melbourne remains AURIN's lead body, which provides some degree of stability. • A second threat arises from the **restricted access model**, which is currently limited to researchers and government personnel. Could a similar application platform be developed by someone else but with a more open model accessible to a wider user-base (e.g. private sector and the public), thus causing AURIN to fall out of use?

Table 2.4 – SWOT Analysis of AURIN Case Study

2.4.3 CGIS – Portland, USA

2.4.3.1 The City of Portland in Oregon, USA is an early adopter of a citywide spatial data infrastructure and provides a good case study of a proven and successful approach in sharing spatial data via a centralised corporate function. The CGIS and the Portland Enterprise GIS Hub (EGH) have been described in numerous articles[5] and publications[6] over the years. The information provided in the case study was gleaned from the Consultant's direct involvement in development the GIS Hub and from recent discussions with the CGIS Manager at Portland.

2.4.3.2 The CGIS is a business unit within the Bureau of Technology Services (BTS). Its role is defined within City policy[7] as "to ensure the City leverages existing investments, eliminates redundancy, promotes standardisation and consolidation and provides business efficiencies to the City using scalable enterprise GIS technologies". It achieves this by providing several functions:

- Supplies master data and business intelligence
- Provides corporate spatial data warehouse and data integration facilities
- Provides application development services

2.4.3.3 **Table 2.5** shows the overview of the Portland built environment application platform.

[5] http://www.esri.com/news/arcnews/fall00articles/cityofportland.html
http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.138.2476&rep=rep1&type=pdf
https://library.esri.com/docs/proc00/professional/papers/PAP504/p504.htm
[6] Mayor Vera Katz – Delivering the Promise of E-Government. In Blackstone, E., Bognanno, M., Hakim, S. (2005) Innovations in E-Government, The thoughts of Governors and Mayors. P196-214
[7] CGIS Policy https://www.portlandoregon.gov/citycode/article/114425

BUSINESS ARCHITECTURE *The Business Architecture view looks at the corporate aspects of the platform such as how it fits within the organisation, the services and products it provides and how it operates.*	
Business services provided A description of the business services and products provided by the unit/organisation such as: spatial data provision, data brokerage, analysis, software provision/sales, user training, etc. Who is the target audience for the platform?	CGIS is a centralised spatial information services function for the City of Portland. According to city policy[7], it provides the following services: • Data publishing to the Enterprise GIS Hub In order to eliminate and/or reduce duplication of data and to provide secure, accurate and up to date data to users, all data that will be used by more than the originating Bureau will be posted and made available on the Enterprise GIS Hub. • Metadata catalogue CGIS supports a central online Metadata system. All Data Custodians are required to ensure that the central metadata repository is maintained and current at all times. The public metadata catalogue is available at: https://www.portlandmaps.com/metadata • GIS Web Mapping Services. CGIS provide the highly popular Portland Maps website, serving city information via web mapping and applications to internal and public audiences. The site is available at: https://www.portlandmaps.com/ • Spatial data distribution CGIS support internal and external data distribution via online data APIs as well as data download utilities that enable data to be obtained in a variety of spatial formats. Externally data APIs are available at https://www.portlandmaps.com/development/ Open data may be downloaded from: https://www.portlandmaps.com/opendata • GIS Application Procurement, Development and Deployment Portland have an Enterprise License Agreement for the use of the GIS software, which is the corporate standard. All software installations are coordinated by CGIS. CGIS provide a highly skilled development team to create and maintain a suite of in house GIS tools and development frameworks. • Coordinate multi-participant GIS efforts A key role of CGIS is to coordinate and support joined-up working arrangements and to enable improvements in cross city workflows through improved access to common spatial data.
Legislation, policies and procedures Are there any specific legislation, statutory instruments, guidance, policies or procedures in place to facilitate the platform?	The role of the CGIS function is defined by City Ordinance[8] In general, exporting and distributing data directly between Bureaus and end users is not permitted on the basis that this can create data integrity issues as well as unmanageable data dependencies.

[8] https://www.portlandoregon.gov/citycode/article/114425

	Data that does not have the minimum set of associated metadata as defined in the CGIS Metadata Standard is not allowed to be distributed either internally or externally. Any exceptions to city policy need to be approved by the Chief Technology Officer (CTO).
Performance management / KPIs How does the unit/ organisation measure its performance against targets and what key performance indicators does it use for each of its services / functions.	Several basic performance measures have been used to assess CGIS, these include: • Reliability and performance of the Enterprise GIS Hub • Quality of data served by the hub in terms of completeness, currency and metadata • Contribution to improvement in delivery of City services (unclear how this may have been achieved)
Governance / institutional arrangements How does the unit/ organisation fit within the organisation (or is it an independent organisation) and what governance arrangements are in place?	CGIS is overseen by the Auditor Office of Portland and the City Auditor is responsible to reviewing progress against agreed funding plans. Data Custodians are currently responsible for defining access requirements, update frequencies and metadata currency. Data Custodians work in conjunction with System Operators to ensure that "due care" is taken to properly protect sensitive data. The City is currently working to develop an enterprise data governance framework[9] to streamline work across departments.
Staffing / resourcing Does the unit/ organisation have dedicate staff; how many people are involved and what roles do they have?	The CGIS Team has a dedicated team of staff of the following roles (around 15-20 in total): – Project Director – Project Manager – GIS Analysts – Programmers – System Analysts – Solution Architects – Application Developers – Data Analysts – Data Administrators
Funding model How was the development funded and how is its operation funded? How are individual products and services charged for? Is the business case for the establishment of the platform available? What are the on-going costs of operating the platform?	CGIS is a corporate service that is funded through a rate model that distributes the costs to bureaus based on their size and use levels. The funding to establish the capability was initially provided centrally through bond financing and a levy on each of the city bureaus / departments. CGIS also received income from application development services and some grant funding. Development and operating costs for the first 7 years of the development were in the order of USD18,000,00 (~USD2.5M/year)
Usage agreements and licensing	None identified or provided at the time of publication of this report.

[9] https://akscf.matsugov.us/akscf/Documents/AlaskaGroup_MattFreid_EnterpriseGIS_080917.pdf

What service agreements and/or licensing is used when accessing the platform services and data? Are there Service Level Agreements in place for the provision of the platform services?	

APPLICATION ARCHITECTURE

The Application Architecture view considers how the suite of applications work together to provide the business services described above, as well as the supporting 'back office' applications required to deliver those services. This view is not concerned with any single end user application but rather on how the platform is constructed.

System architecture / technical building blocks
Describes the major components of the platform infrastructure and how it relates to other systems such as an underlying Spatial Data Infrastructure (SDI). This section should also consider licensing models/costs in cases where proprietary software is used within the platform.

CGIS provides both the spatial data infrastructure and the application services to leverage the available data for a range of stakeholder groups.

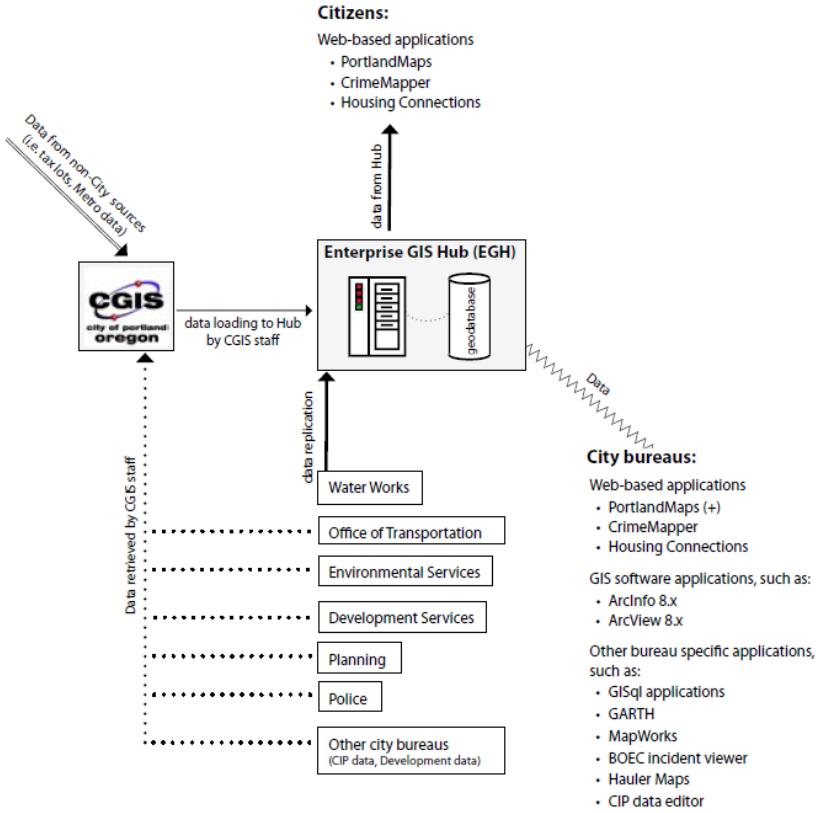


Figure 2.1 – Enterprise GIS Hub Architecture

Figure 2.1 illustrates the high level architecture of the hub and relationship to CGIS. (image from Portland Auditor's report[10])

The chief building blocks of CGIS are:

- CGIS Developer platform
  Portland has developed a software application platform to facilitate the development of web maps and applications, as well as to facilitate the

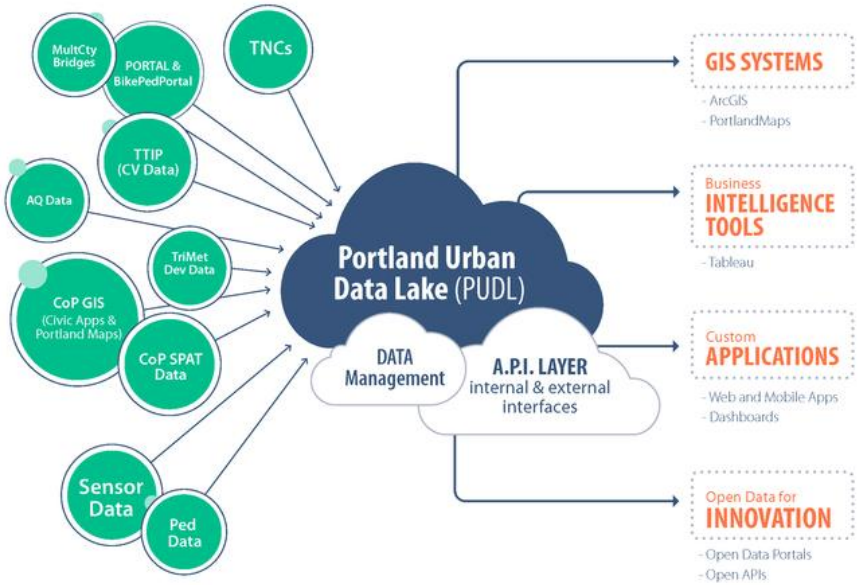
[10] http://efiles.portlandoregon.gov/Record/8310891/

	deployment and use of desktop GIS solutions provided by a software company • A web application framework is built on top of the server web and geoprocessing platform. More recently the City has begun to deploy content onto the online cloud platform. • Enterprise GIS Hub database Comprises an Enterprise Geodatabase hosted within a Microsoft SQL Server database. • A spatial data integration platform Data is fed from source system using a combination of Safe Software FME spatial data transformation platform; various flavours of SQL Server data replication, and custom or third party data connectors.
Applications deployed Describes both the core application components of the platform itself, as well as identifying some of the end-user applications that are supported by the platform. Does the platform present Read-Only data or does it support data creation and update as well?	CGIS Portal provides an internet presence to showcase the services it provides: https://www.portlandoregon.gov/index.cfm?c=28130 Portland Map Reports provides searchable access to tabular data about buildings, permits, roads and addresses: https://www.portlandmaps.com/reports/ CGIS has begun to provide some content via the Online Cloud Web Maps Service, a gallery of the available applications is provided here: https://pdx.maps.arcgis.com/home/gallery.html All installations of desktop GIS software are deployed with the CGIS developed corporate extensions and software such as the CGIS Tool bar. The CGIS Tool bar is the standard toolset that facilitates access to Hub datasets and layers. CGIS also provides a custom built, light weight desktop application which is widely deployed to city users to provide custom functionality by department.
Support for collaboration and public engagement Given the focus of the BEAP we are particularly interested in how other platforms have enabled collaboration between departments, public sector, academia and the public.	CGIS enables and encourages collaboration with both internal and external stakeholder groups, principally by making city spatial data available via streaming web services and downloads. A developer web page on the City Internet site provides links to data and development resources: https://www.portlandoregon.gov/28130 The City has partnered with regional jurisdictions to encourage citizens of the Greater Portland area to actively engage with the available data and services. The CivicApps.org website provides a portal to inform interested parties of opportunities, events and competitions: http://civicapps.org/ Hackathons organised by third parties have begun to appear to pick up the challenge and provide concrete evidence of the interest in leveraging city spatial data. Examples of organised Portland hackathon events are available at these sites: http://www.hackoregon.org/civic-projects/ http://www.greaterportland2020.com/techchallenge/ CGIS do not, however, provide any specific collaboration tools in the form of discussion boards or project coordination tools. Nor have they released any source code to open source community repositories such as GitHub.

Application Programming Interfaces (APIs) provided How are the services of the platform exposed to support end-user application development and what APIs and languages are supported?	Access to published data is provided via a set of published APIs, which can be accessed at: https://www.portlandmaps.com/development/ The APIs provided include: • Address • Parcel Assessment • Land Use • Sewer • Reporting • GIS Online An API for the exposed Server REST services is available at: https://www.portlandmaps.com/arcgis/rest/services
Channels Through what mechanisms can users and applications interact e.g. web, mobile app, desktop application, face to face service desk, kiosks, custom devices, etc?	CGIS is focussed on web based and desktop service delivery. Via an Enterprise License Agreement with a software company, the city has standardised on a GIS desktop software and this is widely installed. Web applications have been designed and developed to adapt to different device types and thus the web mapping applications work well on mobile phone and tablets, as well as desktops. Published APIs enable internal and external developers to further leverage the city's spatial data.
Technologies What technologies / products have been used to develop the platform infrastructure and are they vendor proprietary, open source, custom-built?	The key technologies are: • GIS Desktop, Server and Online • SQL Server database • Safe FME spatial data transformation These are all licensed proprietary software suites.
Interoperability, use of standards What technical standards have been adopted to enable a broad range of technologies to interact with the BEAP?	CGIS has adopted the GIS-based platform which does support numerous OGC GIS and web standards[11].
Security How have security mechanisms been implemented to protect the platform and to authenticate users and manage access privileges?	User management for access to the Enterprise GIS Hub is not known. The GIS-platform online service is on a per user subscription model which allows user groups to be established and these can be used to manage access to data, maps and applications. The platform also supports anonymous access to publicly available items.

[11] http://www.esri.com/software/open/open-standards

Platform monitoring and administrative functionality What functionality has been implemented within the platform to monitor service provision and system health, as well as to support administrative tasks such as usage throttling, fee collection, adding new services and updating existing services?	Monitoring of access to, and performance of, the Enterprise GIS Hub is not known. CGIS content that is accessed via the Online platform will have basic monitoring as provided by the software company.
DATA ARCHITECTURE *The Data Architecture view considers how the data is organised and how the appropriate data is presented to end users and systems. We are interested in the relationship between the application platform and the Spatial Data Infrastructure and thus (if relevant) the data view should consider the distinction between raw/source data from business systems, etc, and the data that is presented to the platform end-user applications. In those cases where the platform is responsible for presenting tailored information products by processing source data sets then the products and production process should be described where possible.*	
Information products / data enrichment Identifies the information products that are presented by the platform as well as describing any processing and enrichment of source data to produce a data product that is re-purposed / tailored for BEAs.	CGIS provides access to city data in a central database hub and presents that data in a way that makes it easy to use. As the only corporate data warehousing function in the city the data is presented to address the needs of a wide range of audiences The data integration 'pipelines' that publish spatial data from source system into the hub thus transform, translate and restructure the data. This process generally involves steps such as: • Filtering out content that is of no value to others • Simplifying data structures • Renaming attributes into standard names • Reclassifying coded values into meanings • Restructuring spatial geometries • Merging local datasets into citywide datasets
Data access rights and agreements This section identifies the types of data agreements between the data providers and the platform provider.	City policy states that all distributed data will comply with the "Data Distribution and Use Agreement Polices"; these are not available online. CGIS does develop data sharing arrangements with each bureau / department but these are not publicly available. Data that is shared publicly via Open Data Hub of the software company does not specify a license type.
Data sources, formats and management When relevant, identifies where source data has come from and how it has been exposed to the application platform.	The City of Portland has standardised for most of its spatial data storage and management applications and consequently most operational GIS data is maintained within a software company Geodatabases within SQL Server. In 2009, Portland became the first city in the United States to adopt an Open Data Resolution (Resolution No. 36735) to encourage the expansion of the technological community by promoting open data and partnerships between City government and the public, private and non-profit sectors, academia, and labour. In May of 2017, Portland formally adopted an Open Data Policy and Program (Ordinance 188356) to expand upon the work completed as a part of the 2009 Resolution, establishing mechanisms for engaging all City bureaus in the proactive

	collection and distribution of City data. The ordinance established Open Data Policy to be committed to the publication, accessibility, and equitable and widespread sharing of data collected and generated by all City bureaus and by private sector companies, non-profit organisations, academic universities and other parties working on behalf of the City. The City is striving to make data open by default[12]. In supporting Portland's Smart City ambitions, CGIS is also supporting the emerging Portland Urban Data Lake (PUDL)[13] (also known as Open Data Cloud Pilot[14]) which is leveraging existing city data sources as well as sensor and regional sources. 
Foundation datasets, reference geographies Identifies the fundamental reference datasets that are used to register other datasets; this could include administrative areas, statistical units, official name gazetteers, etc.	Tax assessment parcels and road centrelines/edges act as the reference datasets within the urban areas.
Data quality assessment / suitability assessment Describes if / how data quality assessments are conducted prior to serving data via the application platform. This could also include consideration for how	Custom spatial data maintenance applications were developed for numerous bureaus using various Desktop tools of the GIS platform. These tools include QA validation rules and enable users to easily navigate between exceptions to correct them (or mark them as known exceptions). It is not known if any further QA is conducted centrally, although it would appear likely that data aggregation and harmonisation steps may fail during Hub updates if no validation is performed.

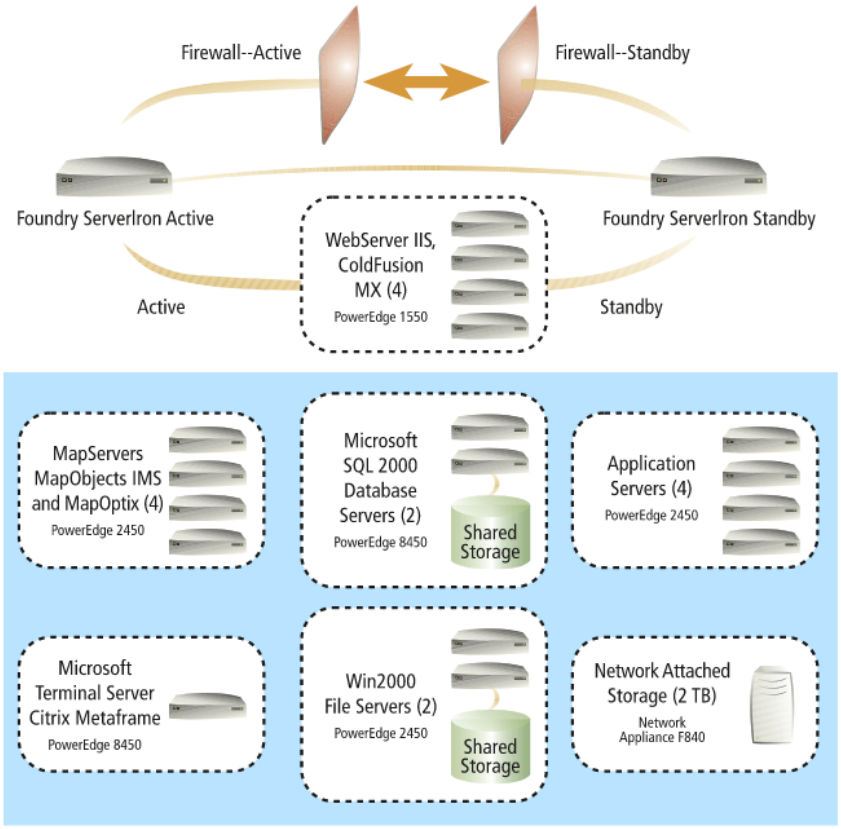
[12] https://www.smartcitypdx.com/projects/

[13] https://www.portlandoregon.gov/bps/76771

[14] https://static1.squarespace.com/static/5967c18bff7c50a0244ff42c/t/5ad9235ef950b729ea0aeca6/1524179809443/isocarp-review-article.pdf

platform users might assess the suitability of a dataset or service for their particular use.	
Support for personal privacy Describes the steps taken to protect personal privacy, particularly when generating information products from several data sources where there is a risk of exposing personal information through data aggregation.	City policies and processes to support personal privacy are not known. It is possible that the current administration is taking a more cautious approach to data protection out of concerns for personal privacy and legal risk[15].
Data model standards Identifies the use of any published data models and lessons learnt from the ways data in which data is presented or described. If the platform supports data creation and data updates then how is this managed and where is the data stored?	CGIS developed internal data models for the Hub based upon the available city data, user data requirements and influence from relevant domain data models such as those developed by the software company, which are provided here: http://solutions.arcgis.com/
TECHNICAL ARCHITECTURE *The Technical Architecture view considers the physical IT infrastructure elements such as the servers and networks that host the platform. Whilst much of this detail is of limited interest in this desktop study, we are interested in general trends that may be relevant to the development of the BEAP.*	
Cloud hosted vs on premise Describes how the application platform is physically hosted, in particular which elements may be cloud hosted and the rationale for that.	CGIS is currently working on a web based structure with on premise infrastructure as support. All public and private callable "GIS Web Mapping Service" functions are required to be provided internally by the Bureau of Technology Services (BTS) to ensure compliance with both architecture and security standards. BTS is responsible for implementing and managing all necessary technology infrastructure related to delivering web based GIS services and applications. This

[15] http://www.invw.org/2016/03/31/data-dustup-bedevils-portland-planning/

	includes but is not limited to hardware, software, networks, support and security. Figure 2.2 illustrates the basic technical architecture[16]  Figure 2.2 – CGIS Enterprise GIS Hub Network Diagram Due to poor network connectivity, early iterations of the Hub were deployed to several sites around the city and were kept in sync by SQL Server replication. The need for local hubs reduced over time as the citywide network improved. Maps, apps and data that are served via Online are obviously cloud-hosted on the software company's Software-as-a-Service platform. The City are currently investigating this form of service delivery.
IMPLEMENTATION AND USER CONVERSION *What lessons can be learnt about implementation and user conversion aspects of the case study platforms?*	
Implementation process and phases Identifies the history of platform development / evolution and the business drivers of each stage	The first business case for CGIS was developed in 1992. CGIS was established in 1997 and the Enterprise GIS Hub was deployed to production in 2002. The Hub was largely developed by an external consulting organisation in two phases – a proof of concept and a production rollout. During this time city bureaus used a 'rich mix' of software platforms and data formats. The Hub enabled them to share data between platforms but this did add complexity to the IT environment. During a subsequent phase, the city adopted a platform of a software company as the standard for GIS and individual departments migrated to use these tools. CGIS supported the bureaus by developing spatial data maintenance tools that extended

[16] http://downloads.esri.com/support/whitepapers/sde_/city-of-portland.pdf

	the core desktop tools to provide an improved data editing and data QA experience, as well as providing support to simplify integration with the GIS Hub. CGIS has always had a strong development team and has been responsible for developing the desktop and web applications that leveraged the Hub data. The current phase has witnessed a move to make the Hub data more openly available in order to support streamlined citywide workflows and to enable businesses and citizens to innovate in new ways.
Uptake / change management Identifies any specific actions that were taken to encourage the adoption of the platform and their success. This could include mandates and incentives. What were the organisational change experiences of gaining acceptance and adoption of the platforms by the user communities?	The development of the Hub was initially funded by contributions from numerous city bureaus on the basis that it would simplify data sharing between them, and reduce / eliminate duplication in data capture and maintenance efforts. A second aspect of the initial business case was to make it easy to find and evaluate spatial data within the City – the time taken in data 'seek and verify' activities was estimated to be of great expense in lost time. Failure of a user to find the best or official dataset could also result in decision makers being misinformed. Initially some bureau staff were resistant to sharing 'their' data via the Hub but their attitudes shifted very quickly once the Hub was deployed and they could see how easy it was for them to access data from other bureaus. Migrating from a mix of GIS applications to standardise on a GIS platform was eased as the tight integration between the GIS desktops and the hub could be seen to reduce the burden of data management and data sharing on the individual bureaus. The release of city open data was very warmly embraced and has enabled CGIS to rely on the community to maintain some applications. For example, the Police CrimeMapper web application that was developed by CGIS has been replaced by third party applications such as CrimeReports that consume the city open data. That application is available here: https://www.crimereports.com/agency/portland-police-bureau-or
Training / publicity Identifies the types and levels of publicity and training to promote the adoption of the platform and platform services.	CGIS was publicised widely both internally and externally during the development of the Enterprise GIS Hub and CGIS services. As the service has become firmly established and adopted throughout the city and other communities CGIS have scaled backed on their publicity.

Table 2.5 – Overview of Portland BEAP

2.4.3.4 The SWOT analysis from the CGIS case study is shown in **Table 2.6**.

Strengths	• Usability – CGIS has invested heavily and consistently in the creation of engaging and easy to use applications. This investment in usability has eased the adoption of CGIS services and applications as people choose to use them in preference to others because they are a pleasure to work with. • AURIN acts as a 'data broker' for its users by managing the usage agreements and licences so that users don't have to negotiate on an individual basis with the data owners. These pre-agreed usage and licence agreements follow open data standards wherever possible, and define clearly how and where the data can be used.

	• CGIS allows applications to be developed to provide meaningful results that the general public, private industry and municipal government can utilise to determine the effectiveness, impact and feasibility of custom hypothetical test cases. • Performance – the application is optimised in terms of structure, database indices and caching such that the system is very responsive to users' requests. This is very important for web applications where users expect web pages to be displayed within 2 seconds or so. • Support for analysis –CGIS is able to present city information in ways that are more conducive to different analysis than the raw data of the source systems. CGIS also makes it easier for city data analysts to interrogate the information. • The Enterprise GIS Hub supports the city Business Intelligence functions. By organising datasets based upon their spatial location, the EGH effectively takes advantage of the common spatial dimension that is inherent in much of the city data and enables a wide variety of disparate datasets to be brought together for analysis. • The use of highly functional and mature proprietary software suite enabled CGIS to make rapid progress when it was initially established. The underlying GIS software suite has changed significantly over the years but has still enabled some familiarity with the tools to migrate and ease the adoption of improvements in the platform. • Transparency – applications such as the Buildable Lands Inventory, Land Use Permits and Map App promote transparency and provides publicly available data in an intuitive and interactive interface. This in turn enhances community-ownership and community-led planning by giving the public a convenient platform to access planning information. • The city of Portland was recently awarded the World Council on City Data (WCCD) ISO 37120 Platinum Certification for its Open Data initiatives17. ISO 37120 includes 100 indicators based on 17 themes showcased on the WCCD Open City Data Portal, enabling comparability and best practices for cities throughout the world.
Weakness	• The use of proprietary software may have enabled rapid progress initially but it's use does potentially limit growth. The GIS software is licensed and priced by the number of seats for the desktop software and by the number of server cores for the server based software. The on-premise GIS software has adopted a 'named user' license model which mimics licensing model of the used software for its cloud hosted Software-as-a-Service Online platform. The Portal and Online licensing models also use a 'service credit' model to pay for additional functionality on a pay-per-use scheme. In all this can prove to be expensive, particularly if functionality is exposed to external users. And whilst the cloud platform does support public access without charge; if content is restricted to specific groups then those users must have individual accounts and 'named user' licenses allocated to them.

[17] https://www.smartcitypdx.com/news/2018/5/3/city-of-portland-becomes-4th-major-city-to-achieve-platinum-certification-for-open-data-efforts

	• This issue can be mitigated to a large extent by exposing data and functionality via open standards-based API's that can be leveraged by any technology, including open source technology. This enables applications not using the same software/GIS platform to be developed on top of those APIs. • The general-purpose nature of CGIS means that the team does not necessarily incorporate any domain expertise for BEAs. This is really a function of the size of the city – there is not sufficient demand to justify domain-specific application platforms such as, for example, Built Environment, Health, and Transportation. A consequence of this is that the city has not invested in the development of data models to specifically address the needs of the Built Environment. • The Enterprise GIS Hub approach was initially developed over 15 years ago to address city spatial data sharing problems; it wasn't designed with some of the new Smart city ambitions in mind. The Portland Urban Data Lake initiative is in the early stages of considering how existing facilities may be leveraged to address new challenges.
Opportunities	• CGIS is very much a city government platform for the City of Portland. The City is part of the Metro area which straddles 3 county boundaries within the state of Oregon in the USA. The different levels of government are responsible for different functions and rely upon inter-agency collaboration. Each level of government has implemented some form of spatial data sharing infrastructure – such as the Metro Map (https://gis.oregonmetro.gov/metromap/) and the subscription-based Metro Regional Land Information System Discovery site (http://rlisdiscovery.oregonmetro.gov/). There is therefore the potential for a wide area, pan government Spatial Data Infrastructure and relevant application platforms to develop. The CGIS approach, which has been proven in this region, could provide a potential solution. • The CGIS platform has focused almost exclusively on 2D spatial data. Urban applications would benefit from the availability of richer 3D city models and CGIS would be well positioned to incorporate support for them. Support for such models is really a prerequisite to being able to adopt BIM across the full lifecycle of building and infrastructure developments. • The CGIS platform provides some support for real-time data from sensors and IoT devices through the GeoEvent Server[18]. This is a rapidly developing area and CGIS is likely to increase its support for these emerging data sources. • Whilst there has been some collaboration and contracting with academia and private enterprise during the development of the platform, the focus has been on developing the internal capability. As CGIS increasingly exposes services through open standard-compliant interfaces, there is a growing opportunity to engage with a broader community to accelerate innovation and application developments.
Threats	• CGIS is corporate function that funded through a levy on other bureaux and departments. Individual levies are based on the benefit received which is assessed through the nature of the recipient and the actual level of use of the

[18] http://www.esri.com/arcgis/products/geoevent-server

	CGIS services. This funding model is supported by city ordinance and is felt to be relatively secure. • The emergence of other high-profile initiatives which potentially overlap with some CGIS services (such as BIM and Smart City initiatives) are regarded as potential competition for CGIS funding, depending on how those initiatives and functions are defined and funded.

Table 2.6 – SWOT Analysis of CGIS Case Study

2.4.4 Relevance of Case Studies to the Development of the BEAP in Hong Kong

2.4.4.1 The principal aspects of the international case studies' experience that are relevant to the development of the BEAP are summarized in **Table 2.7**.

Case Study	Relevance to the Development of the BEAP
Virtual Singapore	• **Management of source data of 3D modelling and data update process**: In this kind of CSDI BEAP project, source data preparation is critical, including geographic/non-geographical data and real time data. Learning from the Virtual Singapore experience, it is important to secure the source data sets with city customer during the early phase of the project. In this Singapore project, the city has a long term and long lasting data recording and geolocation practice with classification. Singapore has the capability to support the experiment to collect new data in real time from smartphones, cameras and sensors, this provides a very good foundation for this project to trigger data daggering, big data analytics and related applications by various government units, industry and academics. The exact level of the source data is also important, without the right level of exact data, some kind of functionality such as simulation, will not have much usage for the customer. Any additional effort to capture the new sets of data will be very costly. • **Business requirement/process**: As the pioneer by applying industry-leading virtualisation, simulation and collaboration capability to smart city area, Virtual Singapore project was started from research project, the good part for research project is that the project can try and use most update/new technology, whereas the bad part is that a clear business objective, business requirements/ business process are not usually in mind. The Virtual Singapore platform has very good support and functionality for business collaboration, which the end user needs to involve the business departments and identify the business requirement/process in the early phase of project. • **Deployment of cloud technology**: Although most of the government users prefer to have on premise solution, the cloud solution is the trend. This project solution is based on public cloud technology. This architecture is cost effective and easier for customer to deploy and expand the applications in the future. Within current cloud technology, security will not be an issue, government users could have secure/private VPN to public cloud. It is easier to maintain, and to support the 3D visualization of the whole city and the collaboration requirements of the citizens. • **Simulation to facilitate applications across disciplines**: With the 3D model setup, simulation is another key element for Virtual Singapore project, there are

	different kind of simulation based on 3D modelling, like shadow, wind simulation, pollution, flooding or evacuation simulation. On one unique digital twin platform, the user can integrate with simulation tools and display simulation results using widget development technology. Different simulations need very specific domain knowledge, it is important to have the right mix of software, development and domain experts to trigger applications across disciplines.
AURIN	• **Federated model**: In recognition of the disparate and widely dispersed (i.e. across Australia) organisations who provide data and utilise AURIN's services and applications, AURIN acts as a portal to the data rather than being a repository in itself. Ownership and management of the data remains the responsibility of the originating organisation. This is important in the Australian political context, where different governments and agencies are unwilling to relinquish control or ownership of their data, but are willing to share it under agreed terms and conditions. The Hong Kong CSDI BEAP is likely to draw its data from a variety of sources, and such similar federated model may be appropriate for the BEAP, where the BEAP acts as an 'application broker', providing access to those people who are authorised to access those applications. Some of these applications may be restricted to internal use by B/Ds, for example, whereas others may be available for full public use. Rights of access will be determined by the data owner, and the BEAP would respect and apply those rights in its access model. • **Software- and platform-agnostic**: AURIN does not try to mandate use of particular software or hardware infrastructure to access its services or host data and applications. Instead it is designed to be as open and flexible as possible so that it can prove a portal into a wide array of data and different kinds of applications. Given that there are already a number of platforms and applications in existence in Hong Kong, it could be considered that the BEAP follows a similar agnostic approach, relying on the use of common data and application standards to enable existing and new applications to be accessible via the BEAP. Attempting to enforce a rigid, closed or proprietary architecture may result in fewer datasets and/or applications being accessible via the BEAP, in turn reducing the BEAP's value and effectiveness as the go-to portal for Hong Kong's built environment. • **Use of open standards for new applications**: Whilst some of the existing BEAs in Hong Kong may not follow open principals, the BEAP may follow AURIN's example and all new applications developed in the BEAP follow open standards and principles to maximise interoperability within B/Ds, or even business and academia. • **Controlling access to data and applications**: AURIN restricts access to researchers and government employees for the full suite of data and applications, and provides only a limited set of data and applications to the public. Whilst this may be considered a weakness of that model (from a best-practice and open data perspective), it is an appropriate model for Hong Kong, given Hong Kong's political and administrative structure. The BEAP may adopt similar model of controlled access to data and applications, but apply the principal that everything is open by default, and a case needs to be made for any access restrictions to be applied. • **A dedicated team of specialists building, managing and governing the BEAP**: A success factor that AURIN has in common with other best-practice application platform examples is its clearly-defined and well-resourced

	governance and operational model. Operating and developing an application platform and data portal is not a small task and the importance of a well-resourced team to undertake this should not be underestimated. The BEAP will be a living platform – not a static product – and will always require active development and management if it is to continue to meet its aims and deliver a valuable service to Hong Kong.
CGIS	• CGIS's centralised approach to corporate data sharing and application development has undoubtedly provided a successful model for the City of Portland. This section considers the applicability of Portland's CGIS model to Hong Kong's BEAP objectives. The key characteristics of the Portland CGIS model that will be considered are: o All-purpose urban platform o Centrally managed hub and spoke topology o Open data and application APIs o Based on proprietary software packages o Central application development team o Centrally funded • **All-purpose urban platform**: CGIS provides a general-purpose urban platform that functions as both an SDI and an application platform. Furthermore, CGIS supports all application areas, rather than specialising on just BEAs. This arrangement appears to be well suited to a city the size of Portland with a population of ~650,000 people; Hong Kong, on the other hand, has well over 10 times the population of Portland and the suitability of a single combined corporate CSDI and application platform for all themes may be unwieldy. One downside is that a general-purpose platform team may find it difficult to maintain a balanced focus across all themes and may not have the necessary depth of expertise in all data themes. • **Centrally managed hub and spoke topology**: CGIS harvests data from departmental data sources (the spokes) and presents it in a centralised spatial database (the Enterprise GIS Hub). This is in contrast to larger-area initiatives such as AURIN and European INSPIRE programmes that adopted a federated approach to data publishing in which the independent data providers self-publish data. The advantages of the centralised approach have been clear: o The ability to repurpose data to produce actionable datasets (or information products) to address specific application needs; o The ability to change/improve data products in one place without needing all publishers to update their procedures at the same time; o Reliable and high performance access to data in one place for applications. • As a territorial government, Hong Kong has more in common with Portland and Singapore than with the multi-state Australian and European situations, as the participating organisations in Hong Kong share a common network and governance regime. This means that Hong Kong has more technical options available to facilitate data sharing and could therefore adopt a centralised approach. The CSDI will eventually address the key data sharing issues by

providing a corporate data sharing infrastructure which in effect will provide the BEAP with a single means of accessing government data. The BEAP will harvest relevant data from the CSDI and refines it to produce actionable datasets to support the applications.

- **Open data and application APIs**: Recently, CGIS has begun to expose standardised data and application APIs to enable a wider pool of application developers, both within government and externally, to leverage the available data. Opening up the data and application services provides a number of benefits, including:

    - Improved opportunities for innovation – a wider pool of developers means that there is a greater pool of ideas that may be applied to application development, seeking to use it in new ways and to solve a wider range of problems. Innovation can come from surprising sources when new people with different experiences and expertise can 'cross pollenate' their ideas with others to create new things. Pursuing an 'open by default' policy greatly increases the opportunities for innovations. This is an approach that has become widely adopted around the world and clearly offers opportunities for Hong Kong as well.

    - Improved transparency – publishing government datasets and related application functionality provides opportunities to improve government services and enable economic development[19].

    - Greater return on investment – Repurposing data to support specific application uses and then exposing those data and applications via open/standard APIs enables greater use to be made of existing assets and therefore greater value to be derived from them, both internally and externally.

- **Based on proprietary software packages**: CGIS have developed the EGH and their applications using proprietary technology from a commercial software company. This enabled the team to make rapid progress when CGIS was initially established but does incur annual licensing costs. In the beginning, there were very few open source options and the vast majority of GIS implementations were based upon proprietary vendor technologies. The picture is very different today, and whilst the software company has undoubtedly developed their product set to a very impressive degree, the market place has changed dramatically. Many vendors have disappeared, many GIS/spatial technologies have been absorbed into mainstream IT, new niche products have developed, and open source technologies, solutions and communities have improved dramatically. The software company and other proprietary solutions offer benefits in terms of proven commitment, professional support and relatively large pools of skilled users and developers; the down side is that they incur regular license costs, the code is hidden so the release of patches and new features is at the behest of the vendor and source cannot be inspected for potential malware. The same points are almost mirrored in the current crop of cloud hosted services; hosted services offer advantages in terms of ease of maintenance, reliability, etc but are currently relatively expensive and difficult to customise to meet specific needs.

- Open source solutions have become very popular around the world on account of their free licensing model, large communities of active developers, pace of development and feature incorporation and openness for inspection and testing. CGIS have incorporated some open source libraries such as JavaScript Bootstrap

	but, on the whole, have stuck with the software company technologies throughout. • **Central application development team**: CGIS has a small in-house development team that leverages the Enterprise GIS Hub and their application platform to develop business solutions for city departments and bureaus. The team has been stable over many years and has significant expertise in both application development, city spatial data, and city business processes. This enables them to develop applications very efficiently, but it has taken many years to refine this capability. For larger projects CGIS has contracted out to system integrators and application developers. With the recent release of application APIs, CGIS are now enabling a much broader group of application developers to leverage the platform. This provides a good model for Hong Kong in which the BEAP could develop and sustain a core development team that has the in-house expertise regarding the application platform and how it can be used, and can support a growing community of internal and external developers who leverage the platform to address a wide range of business needs. • **Centrally funded**: CGIS is centrally funded through a levy on other city departments and bureaus, based upon their usage of the platform, the team also charges for application development activities. The central funding sends a clear signal that CGIS is a long term and core function of the city and that consequently individual departments, etc. can have the confidence to rely upon CGIS in place of operating their own internal development services. The funding model also provides stability to CGIS and its staff, enabling it to develop as a CoE with significant expertise in all core areas. As this model demonstrates commitment and enables the function to develop a strong team with confidence, it may provide a useful reference for the BEAP.

Table 2.7 – Relevance of the Case Studies to the Development of the BEAP in Hong Kong

2.5 Local Experience

2.5.1.1 Apart from international case studies, this Study has also reviewed the local experiences regarding development of applications and platform to enable better use of the available data.

2.5.2 Public Sector Information (PSI) Portal

2.5.2.1 In recent years, the Government has also been working towards enabling the sharing of spatial and non-spatial data through the establishment of the portal. To step up the setting up of the PSI portal for release of the Government information /data to the public, the Financial Secretary announced in the 2015-2016 Budget that all Government information/data would be released in digital formats free online. In 2015, the OGCIO launched the revamped the PSI portal (data.gov.hk) to encourage more creative re-use of data. The portal provides more than 4,000 datasets in 18 broad categories such as weather, health, population and transport.

[19] https://www.gov.uk/government/publications/transparency-and-open-data

2.5.3 Hong Kong 2030+

2.5.3.1 Hong Kong 2030+, which is a comprehensive strategic study to update the territorial development strategy built upon the foundation of the "Hong Kong 2030: Planning Vision and Strategy" promulgated in 2007 and has revisited the planning strategy and spatial development directions beyond 2030 in the light of the dynamics and challenges ahead. It represents the Government's vision, policy and strategy for the territorial development of Hong Kong beyond 2030. A visionary, proactive, pragmatic and action-oriented approach is adopted to ensure a focused public dialogue on the key planning issues critical to future development and a timely response to the changing circumstances in and outside of Hong Kong[20].

2.5.3.2 In the Hong Kong 2030+, there were three building blocks of Territorial Development Strategy built in order to achieve the vision and overarching planning goal:

- **Building Block 1: Planning for a liveable high-density city** – Enhancing liveability in our compact high-density city by retrofitting the densely developed urban areas and optimising development in NDAs;
- **Building Block 2: Embracing new economic challenges and opportunities –** Equipping Hong Kong with land and space, supporting infrastructure and human capital for the economy to move up the value chain by promoting a diversity of economic sectors, innovation and technology as well as quality jobs with a range of skills;
- **Building Block 3: Creating capacity for sustainable growth –** Creating development capacity while enhancing the environmental capacity for the sustainable growth of Hong Kong.

2.5.3.3 Under Building Block 3, an integrated CSDI and an ICT platform were specifically suggested to act as tools to support territorial planning and the planning of NDAs and neighbourhoods under the SGR city development framework.

2.5.3.4 There are lots of issues relating to planning and development raised under the three Building Blocks that need to be further explored and analysed, in which the CSDI and ICT platform would undoubtedly serve as a platform to trigger various functions and applications to address and solve the issues relating to planning and development of the built environment.

2.5.4 The Blueprint

2.5.4.1 The latest edition of the Digital 21 Strategy entitled "Smarter Hong Kong, Smarter Living" champions wider use of sensors, big data analytics and IoT technology to establish a smarter city infrastructure for more efficient, timely, responsive and informed municipal management.

2.5.4.2 Released in December 2017, the Blueprint[21] outlines the vision and mission to build Hong Kong into a world-class smart city by mapping out development plans and providing a clear and concrete direction for smart city development in Hong Kong. The vision of the Blueprint is to "embrace innovation and technology to

[20] http://www.hk2030plus.hk/index.htm
[21] https://www.smartcity.gov.hk/

build a world-famed Smart Hong Kong characterised by a strong economy and high quality of living" with the following missions set:

- to make people happier, healthier, smarter and more prosperous, and the city greener, cleaner, more liveable, sustainable, resilient and competitive;
- to enable the business to capitalise on Hong Kong's renowned business-friendly environment to foster innovation, transform the city in a living lab and test bed for development;
- to provide better care for the elderly and youth and foster a stronger sense of community. To make the business, people and Government more digitally enabled and technology savvy; and
- to consume fewer resources and make Hong Kong more environmentally friendly, while maintaining its vibrancy, efficiency and liveability.

2.5.4.3 According to the Blueprint, initiatives were proposed under six major areas, namely Smart Mobility, Smart Living, Smart Environment, Smart People, Smart Government and Smart Economy. Under the Smart Government, it is proposed to develop the CSDI by 2023 to facilitate sharing of geo-spatial data across government departments and G2B applications, echoing the formation of the CSDI-BEAP platform, which is tasked to identify the potential applications with key functions focusing on inventory, visualization and analysis.

2.5.5 Common Geographic Information System Platform (CGISP)

2.5.5.1 In view of data of various B/Ds stored under different systems and formats according to individual departments' requirements to support their own operational needs, a feasibility study to explore the establishment of CGISP was commissioned under the Detailed Design Study for the Fanling North (FLN) and Kwu Tung North (KTN) NDAs to examine possible ways to establish a coherent information system to assist the NDAs development, as well as to facilitate planning, construction, monitoring and maintenance work; decision making and public consultation.

2.5.5.2 According to the recommended CGISP Application Solution Option, apps approach is recommended to organize all applications into different apps under a web portal (i.e. Apps is an application centric grouping of functions and required data) to increase the usability.

2.5.5.3 The CGISP can interact with the future BEAP by sharing applications with each other through a common portal, where applications under each platform are able to be searched and accessed.

2.5.6 Study on Development Strategy of a CSDI (CSDI Study)

2.5.6.1 With the release of the findings of HK2030+ and the Blueprint, the importance of spatial data as a strategic asset for Hong Kong is duly recognised. In 2017 Policy Address, the establishment of the CSDI was mentioned under the umbrella of the smart city. The Government has committed to develop the CSDI in order to provide Government departments as well as public and private organisations with an information infrastructure to share spatial data, support various smart city applications, and support the implementation of smart city. In 2017, DEVB commissioned the CSDI Study, which formulated an effective development framework and implementation to take forward the CSDI initiative from a "joined-

up government" and "spatially enabled society" perspective with initial focus on land and infrastructure planning, development and management in Hong Kong.

2.5.6.2 This Study builds upon the existing mechanisms and systems of different stakeholders as well as relevant projects such as the CGISP and the development of Centralised Data Infrastructure in Kowloon East.

2.5.6.3 As recommended in this Study, whilst individual agencies continue to be the "owner" of their spatial data stored in their individual systems, fundamental data and the metadata for all available spatial data are expected to maintain a copy or store in the CSDI platform centrally to enable quicker access and easier discovery. It is targeted for the full operation of the CSDI portal by end 2022, in which about 70 additional datasets would be rolled out in phases (on top of the 79 datasets currently under the Hong Kong GeoData Store), first within Government by end 2021 and then to the public by end 2022. The BEAP would obtain necessary spatial data from the CSDI platform.

2.5.7 Developing Kowloon East into a Smart City District – Feasibility Study (Kowloon East Study)

2.5.7.1 In the 2015 Policy Address, the Chief Executive stated that the latest Digital 21 Strategy envisioned that the Government would make wider use of sensors, IoT and big data analytics for better public services and sustainable social and economic growth. Moreover, he announced that the Government would use Kowloon East as a pilot area to explore the feasibility of developing a smart city. The Kowloon East Study is commissioned in early 2016 to review, investigate, and produce feasible development options and implementation strategy to develop Kowloon East into a smart city district in terms of its strategic setting, constraints and opportunities.

2.5.7.2 Depending on the experience gained from Kowloon East on the use of smart city facilities, the Government can explore the introduction of innovative methods and technologies in infrastructure provision, land development and urban management in the new development areas, and the use of ICT, such as IoT, sensors and big data analytics in municipal planning and management so as to integrate the various intelligent and environmental measures put forward by the Government and the business sector, and adopt the concept of revitalising water bodies to build smart communities with comprehensive functions.

2.5.7.3 With ICT acting as a crucial tool to enhance the efficiency of smart city initiatives, the applications developed in the PoC trials (e.g. Persona and preference-based wayfinding for pedestrians, Real-time road works information, etc.) could link up with or even be stored in the BEAP in the future for further scale up to cover the entire Hong Kong.

2.5.8 Findings of Departmental Visits

2.5.8.1 During the course of the Study, the Consultant has conducted visits to various B/Ds in order to have a quick investigation on the necessary applications, information and related data/datasets.

2.5.8.2 Key observations from departmental visits include the following:

- Each department has its own system for asset search and visualization, which is too specific for their own operations

- One common denominator of requirements of B/Ds is to be able to have a common data platform/ planning & technical information review hub to facilitate speedy and accurate data/ information exchange and review
- Data acquired from other departments are often updated by request or periodically, and most of time are not the latest version as a result
- Most data of departments are updated manually or by contractors according to their own management systems
- Most data of departments are 2D based and some of them are not spatially ready nor geo-tagged
- Due to sensitivity and confidentiality concerns, some of the departmental data may not be able to be shared easily

2.5.8.3 After the departmental visits were conducted, it was found out that each department have their own expectations and suggestion on potential collaborations between government B/Ds. The following are the potential applications could possibly address those concerns:

- Planning and Development Feasibility and IA Review Platform
- Visualization of Existing and Planned Development and Infrastructure Projects in Hong Kong and Greater Bay Area
- Digital Underground Space and Utilities
- Site Search for Housing, Land and Government Facilities
- Landuse Monitoring and Analytics, Data Update Mechanism through AI
- GIC Facilities and Open Space Analysis
- Visualization and Analysis of Green/Blue Social Economic, Demographic, Conservation, Heritage, Agricultural Information
- Appraisal of Development Proposal
- Connectivity Analysis
- Scenario Generation – Planning and Development Toolset
- City Critical Information Sharing Platform
- Real-time IoT Analytics

2.5.9 SWOT Analysis and Lessons Learned from Previous Local Studies Relevant to the BEAP

2.5.9.1 The SWOT analysis and key learning from departmental visits and previous local studies relevant to the BEAP have been summarised as below:

Strengths	• The initiatives on driving Smart City Development has set a good scene for on-going development of the CSDI and its related initiatives • The governance structure of the CSDI clearly identify and address the responsibilities of roles covering institutional arrangement, built

	environment applications and formulating the data and technical standards • The CSDI would facilitate the collaboration among B/Ds in the development of potential applications
Weaknesses	• B/Ds focus on tackling individual issues and develop their own systems making it harder to foster the co-operation and collaboration among B/Ds • Different proprietary software leads to different kinds of data format and standards • Many of the B/Ds' data are not geospatially ready
Opportunities	• Implementation of the BEAP requires intensive collaboration and co-operation among B/Ds which presents a great opportunity to build rapport among B/Ds • Potential to improve efficiency, transparency and the support for decision making in planning and development • Further encourage the development of open data in Hong Kong • Engage the public to provide input and ideas, leading to an incubation of creativity and participation from the public
Threats	• Requires extra resources to compromise among different parties, an effective institutional set-up is needed to incorporate multiple B/Ds • Resource implication for the establishment of the BEAP, which may hinder the investment on future development of the BEAP • Current legislations may impose potential obstacles to develop certain technologies

2.5.9.2 Details of the findings of the local experiences can be found in the "Final Technical Report on Desktop Review" of this study.

2.6 Key Lessons Learned from Overseas and Local Experiences

2.6.1.1 On the basis of lessons learned from the overseas case studies, local experiences and the Consultants' own assessment of current developments and best practice in the built environment application realm, the following four key building blocks that need to be considered for the successful implementation of the BEAP.

- Applications Development;
- Actionable Data[22] for Applications Development;

[22] "Actionable data" is a term used in the IT (and spatial) industry for at least the last decade. Typically, actionable data is: Available (ready to be used by the applications); Useful (able to be acted on); Relevant (content of the data is relevant to the query that is being made of it). Based on the findings of the three overseas cases, actionable data was found as a fundamental element of an application platform, therefore it is recommended for the development of BEAP.

- Technical Infrastructure; and
- Business Architecture and Operating Model.

2.6.1.2 Within each of these key building blocks, a set of essential components should be taken into account in the course of future development of the BEAP, which are shown as below:

Application Development

- **A wide range of applications** – The BEAP should provide a wide range of applications from cross-sector sources via an application portal
- **Standardised APIs for application –** The BEAP should publish standardised application APIs to encourage and enable application development
- **Application-focused with data as an enabling factor** – The setup of the BEAP and the functions it provides should be driven by the end users
- **Open standards in applications development** – Applications hosted by the BEAP should be built to open standards

Actionable Data for Applications Development

- **Actionable data** – The BEAP should make available a wide range of "actionable data" to support the use cases and applications, with a focus on open data standards and licensing. After due consideration, all data the BEAP adopts will come from the CSDI platform
- **Open standards for actionable data** – Just as the use of open standards in application development is highly desirable, the BEAP should consider the adoption of open standards for any actionable data it produces

Technical Infrastructure

- **Relationship with the CSDI** – The BEAP should be supported by the CSDI (and/or other corporate function(s)) which provide access to the fundamental or/and common sharable data required by the applications
- **Innovative platform** – The BEAP should be an innovation-oriented platform with an open, flexible and scalable supporting infrastructure and platform design that is vendor-agnostic
- **Security and access controls** – Appropriate security and access controls should be well embedded into the BEAP

Business Architecture and Operating Model

- **Clear strategic vision** – A clear strategic vision, direction and scope for the BEAP is essential
- **Valuable business services** – The BEAP should provide a set of services tailored to the needs of decision makers and built environment professionals
- **Executive level sponsorship** – The BEAP should have executive level sponsorship with strong financial backing, clear funding model, robust institutional setup and legal framework
- **Well-defined governance model –** The BEAP should have a well-defined, inclusive governance model

- **Collaborative operational model** – The BEAP should employ a needs-led, ground-up, cross-sector collaborative operational model
- **Dedicated team of specialists –** A team of dedicated specialists and domain experts are fundamental to the success of building, operating and developing the BEAP

3 OVERALL DEVELOPMENT FRAMEWORK OF THE BEAP

3.1 Key Recommendations in Stage 1 of the Study

3.1.1.1 Based on the findings from the desktop reviews and departmental visits, an overall development framework which guides the progressive development and implementation of the BEAP are proposed. Critical components and factors for success of the BEAP have been identified and the measures leading to its success are recommended as well. This section will recap the key recommendations of the BEAP set out in Stage 1 of the Study including the mission, objectives, guiding principles and the conceptual model for the BEAP with four building blocks (i.e. Application Development, Actionable Data for Applications Development, Technical Infrastructure and Business Architecture and Operating Model).

3.1.2 BEAP Mission

3.1.2.1 The BEAP will function as a CoE for built environment applications in Hong Kong by providing a focal point that brings together relevant expertise from throughout the city to promote collaboration in the development and sharing of best practices and knowledge.

3.1.2.2 It will provide a set of applications developed for specific needs of the built environment. If an application is identified as relevant to multiple users, it can be accepted as a common application in the context of the CSDI upon the endorsement of the CSDSC.

3.1.2.3 The BEAP is geared towards facilitating the application of ICT in city planning, infrastructure/engineering, and environmental works, which aims to improve works of B/Ds with applications.

3.1.2.4 More importantly, the BEAP aims to improve efficiency, transparency and support for decision making in planning and development, and hence, fostering interdepartmental co-operation and synergy for policy formulation, decision making, resource management, efficiency as well as the delivery of high quality services to the public.

3.1.3 BEAP Objectives

3.1.3.1 The BEAP will address the following objectives:

- To foster co-operation, collaboration, co-creation with Government departments through application and data/information sharing, and knowledge building for mutual benefits, in a wider context among business, academia and the public in the long run;
- To improve B/Ds efficiency, transparency and the support for decision making in planning and development;
- To take forward the CSDI development strategy and support the smart city initiatives in the areas of city planning, infrastructure/engineering and the environment;
- To enable the development and operation of the applications;

- To provide a mean of access to the applications; and
- To gather and prepare source data into an actionable format suitable for consumption by the applications.

3.1.4 Guiding Principles

3.1.4.1 There have been numerous studies carried out in the recent past for both Hong Kong and elsewhere that provide observations and best practice assessments of the development of spatial data infrastructures and associated applications. On the basis of lessons learned from the overseas case studies that we discussed in previous sections and the Consultants' own assessment of current developments and best practice in the BEA realm, there are four key building blocks that need to be considered for a successful development and implementation of the BEAP, which covers applications development, data, technical infrastructure and business architecture.

3.1.4.2 **Table 3.1** lists out the guiding principles of each building block.

Building Block	Guiding Principles
Applications Development	• A wide range of applications from cross-sector sources provided via an application portal • Standardised APIs for applications published to encourage and enable application development • Application-focused with data as an enabling factor • Open standards in applications development
Actionable Data for Applications Development	• Actionable data to support the use cases and applications • Open standards for actionable data
Technology Infrastructure	• A link with the CSDI to enable access to common sharable data • Innovative platform with an open, flexible and scalable supporting infrastructure and platform design • Security and access controls embedded into the BEAP
Business Architecture and Operating Model	• Clear strategic vision • Valuable business services tailored to the needs of decision makers and built environment professionals • Executive level sponsorship with strong financial backing, clear funding model, robust institutional setup and legal framework • Well-defined governance model • Collaborative operational model • Dedicated team of specialists

Table 3.1 – Guiding Principles under the Four Building Blocks for the BEAP Development

3.1.4.3 The conceptual model of the BEAP is developed based on the four building blocks and corresponding principles, where the four building blocks and corresponding principles are derived based on the findings from the Desktop Review and stakeholder involvement. **Figure 3.1** illustrates the development approach of this BEAP conceptual model.

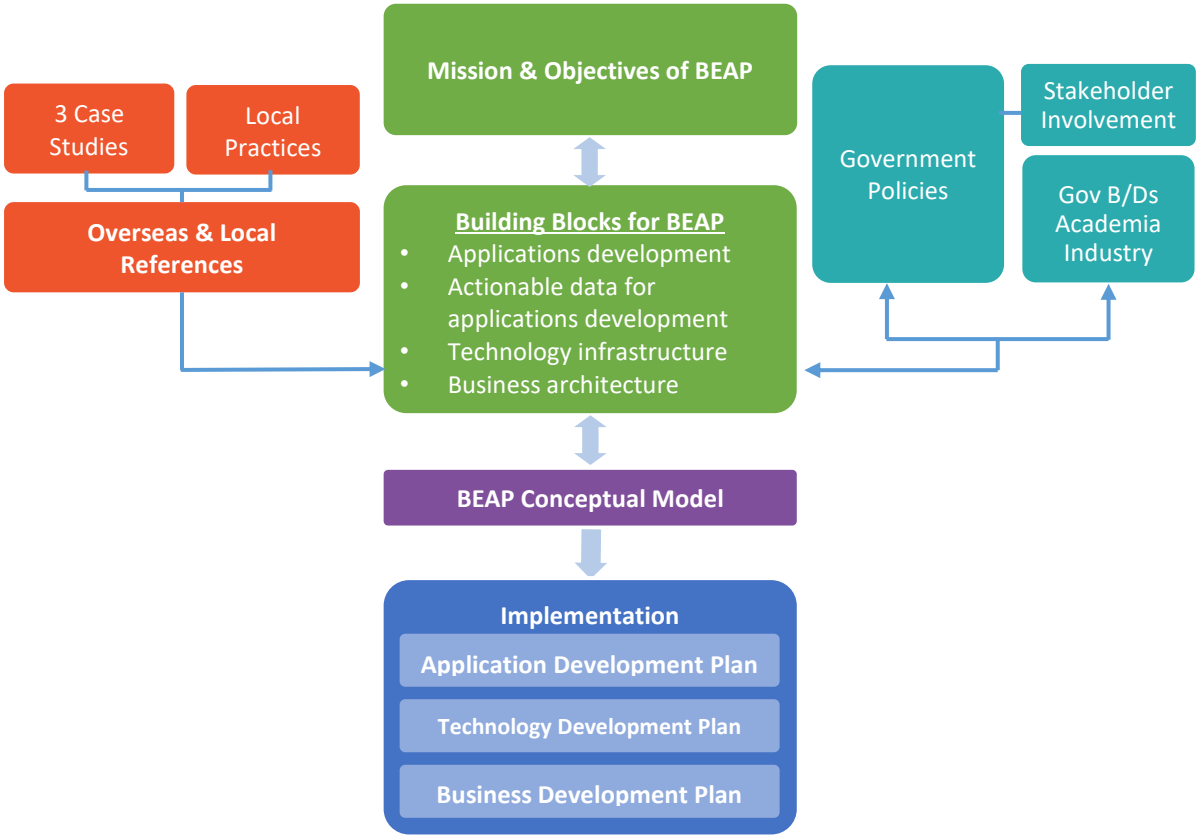


Figure 3.1 – Formulation of an Overall BEAP Conceptual Model

3.1.4.4 The BEAP is envisaged to comprise a team to provide a set of services to support built environment professionals. Those services include development and hosting of BEAs and provide necessary support to the uses.

3.1.4.5 The main elements of the BEAP are illustrated by **Figure 3.2**, and are introduced below.

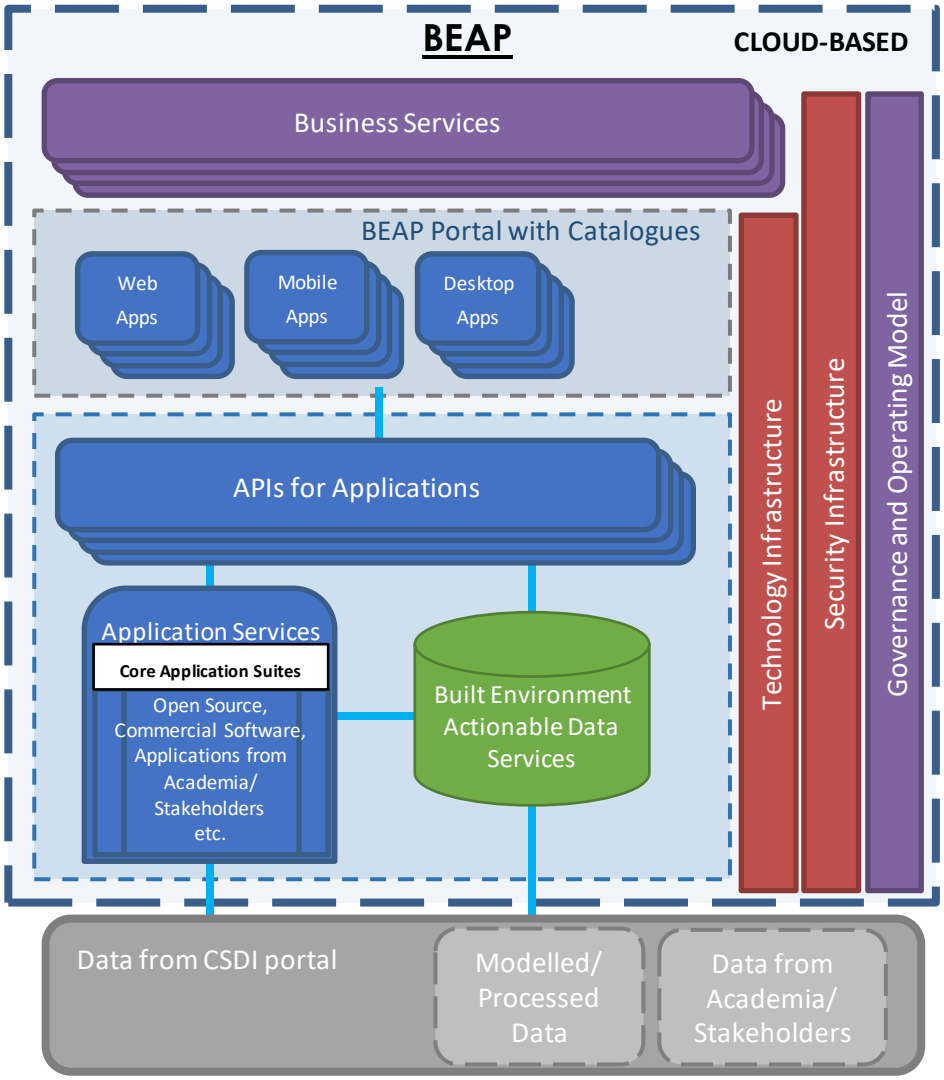


Figure 3.2 – BEAP Conceptual Model

3.1.4.6 The BEAP conceptual model as a whole comprises four building blocks with its associated elements. The content of each element under each building block is described as follows:

Applications Development

- **BEAP Portal with Catalogues:** A web-based portal serves as the users' access point to applications. It provides an applications services catalogue that allow users to search for and access to the required services. The portal could also provide collaboration tools to enable professionals to work together.
- **Built Environment Applications:** Through the BEAP portal, the applications are tasked to address specific built environment requirements. The applications include online Web Apps, Mobile Apps, or downloadable Desktop Apps from the Application APIs. Applications, data and collaboration tools are listed and searchable through the Catalogues provided in the portal.
- **APIs for Applications:** Common built environment application functionality may be hosted online and exposed to other application

developers via standard/open APIs. These APIs can be further linked with the CSDI which would enable a more effective and efficient access to the source data.

Data for Applications Development

- **Built Environment Actionable Data Services:** Data obtained from the CSDI portal would be specifically processed or 'enriched' to support the needs of built environment applications.

Technical Infrastructure

- **Technology Infrastructure:** The fundamental hardware and software on which the BEAP applications and data reside and operate.
- **Security Infrastructure:** The security policies, procedures, user control, tools and resources to ensure that any sensitive information used in the BEAP would not be released to whom should not have the right of access.

Business Architecture and Operating Model

- **Business Services**: The services provided by the BEAP to the user community such as application development, application hosting, etc. Applications provided to different user communities such as B/Ds, academia and public can be different.
- **Governance and Operating Model:** The legal basis for the BEAP, together with the appropriate policies, accountabilities, organisational setup and governance structure to ensure that the BEAP operates efficiently and effectively and delivers value.

3.1.4.7 To implement the BEAP conceptual model, four plans, namely Application Development Plan, Technology Development Plan, Business Development Plan and Implementation Plan are proposed. The ideas of these four plans are illustrated in the ensuing sections.

3.2 Application Development Plan

3.2.1.1 The application development plan consists of applications and data architecture, corresponding to the applications and data building blocks of the BEAP conceptual model.

3.2.2 BEAP Application Architecture

3.2.2.1 As an application-centric platform, the BEAP will enable the development of applications in the built environment realm and will enable potential users to discover existing applications and supporting datasets that may be useful to them. It involves the contents of the first two building blocks.

3.2.3 BEAP Portal with Catalogues

3.2.3.1 The BEAP curated collections of applications and services will be accessible via a web portal (the BEAP Portal) that will enable users to engage with the BEAP and discover relevant resources via application gallery.

3.2.3.2 An applications catalogue (i.e. linking to Web Apps, Mobile Apps and Desktop Apps) will enable users to search for, interact with, or download built environment applications. The distinction between application and web map can be rather

blurred as mapping platforms enable maps to be published as applications, complete with the specific tools for each application.

3.2.4 APIs for Applications

3.2.4.1 In order to maximize the value that may be obtained from the built environment applications in Hong Kong, the applications must be made available in an accessible manner. Rather than requiring users to download applications, application services enable applications to be stored centrally and served online via http web addresses (URIs). APIs enable a wide variety of software applications to access online functions by providing a published interface to the applications via a set of programmatic functions that can be used directly by external programs to access and use the applications.

3.2.5 Built Environment Actionable Data Services

3.2.5.1 According to the proposed conceptual model, the BEAP will develop a set of territory-wide information products to that are tailored to support built environment applications. These "actionable" datasets will be designed to enable applications to work responsively and seamlessly across the territory. They will take the "common spatial data" from the CSDI and process it to produce "built environment-specific spatial data" that is optimised and ready for use within built environment applications. This spatial data, if become sharable and discoverable, can be fed to the CSDI portal for dissemination.

3.2.6 Access to Source Data

3.2.6.1 Upon implementation of the CSDI, CSDI would serve as the main data sources to support the operation of the BEAP and the applications. There are other enterprise initiatives that could potentially influence the form and function of the CSDI and BEAP such as: Master Data Management, Data Warehousing, Business Intelligence, Real-Time data, IoT/Sensor data, Big Data Analytics, Records Management, Electronic Document Management and Smart Cities. The relationships between the CSDI, the BEAP and other related enterprise initiatives are evolving and may present opportunities for improved ways of working. Close liaison will be kept with the responsible agent of the CSDI regarding the use of data during the implementation stage of the applications.

3.2.6.2 In addition to Government data, in the long run, it is foreseen that academia and non-government stakeholders will have their own applications and datasets that can be integrated with the applications and data services throughout the operation of the BEAP.

3.2.7 Identification of 30 Application Types

3.2.7.1 Departmental visits to B/Ds had been conducted to understand the existing platform used by B/Ds, the current data sharing practice and their common requirement on applications. All visited B/Ds have their own information platform to store their own data and applications to support their daily operations.

3.2.7.2 30 application types have been identified and consolidated taking into account the requirements of the Study Brief, feedbacks collected from B/Ds and departmental

visits, which set out the direction for development of proof of concepts of the test case for the BEAP. Details of the 30 application types identified are shown below:

1. Site Search for Housing, Land and Government Facilities
2. Planning and Development Review and Impact Assessment Review Platform
3. Landuse Monitoring and Analytics, Data Update Mechanism through Artificial Intelligence (AI)
4. Appraisal of Development Proposal
5. Connectivity Analysis
6. Scenario Generation – Development and Design Toolset
7. GIC Facilities and Open Space Analysis
8. Digital Underground Space and Utilities
9. Visualization of Existing and Planned Development and Infrastructure Projects in Hong Kong and Greater Bay Area
10. Visualization and Analysis of Green / Blue, Socio-economic, Demographic, Conservation, Heritage, Agricultural Information
11. City Critical Information Sharing Platform
12. Real Time Internet of Things (IoT) Analytics
13. Public e-Engagement platform
14. Future redevelopment
15. Noise assessment
16. Air quality assessment
17. Traffic impact assessment
18. Air Ventilation assessment
19. Environmental impact assessment viewer
20. Building plan and proforma checking
21. BIM/GIS integration
22. Tree management system
23. Data update and plan production automation tool
24. Data inventory and document retrieval system
25. Common platform for departmental data
26. Mobile apps for site inspection
27. Visualization tool of analysis result
28. Peer to peer group chat for projects and events
29. Integration of smart phone and AR/VR
30. Automatic notification of data updating

3.2.8 Selection and Prioritization of Potential Application Types

3.2.8.1 With the general ideas of the application types identified in the above section, a set of principles and criteria have been derived to enable the identification and prioritisation of the potential application types for the BEAP. This following section explains the principles and criteria to be adopted to assess the potential application types.

Key Principles of Selecting Potential Application Types

3.2.8.2 As stated in the Study Brief Section 2.7, the key BEAP objectives are to foster co-operation, collaboration and co-creation with Government departments through application and data/information sharing, and knowledge building for mutual benefits, before extending to business, academia and the public.

3.2.8.3 During the departmental visits, B/Ds expressed their thoughts that they were sceptical whether there are any "common" applications to be created, as it would be difficult to come up with applications that get departments involved in other departments' work.

3.2.8.4 Therefore, the following principles were derived from the Study Brief and the findings from departmental visits.

1. Benefits to more users – one of the aims of the BEAP's applications is to encourage co-operation, collaboration and co-creation among B/Ds. Applications that could be co-created and utilized by multiple B/Ds need to be prioritized.
2. User driven – a collection of applications wish list such as data analysis and visualization were gathered during the departmental visit. These applications can facilitate and enhance the daily operational work for B/Ds.
3. Policy driven – each B/D has works that are required by key Government policy and initiatives, or as part of department's obligatory duty. Toolset incorporating regulations and policies can be developed to improve work efficient and accuracy.

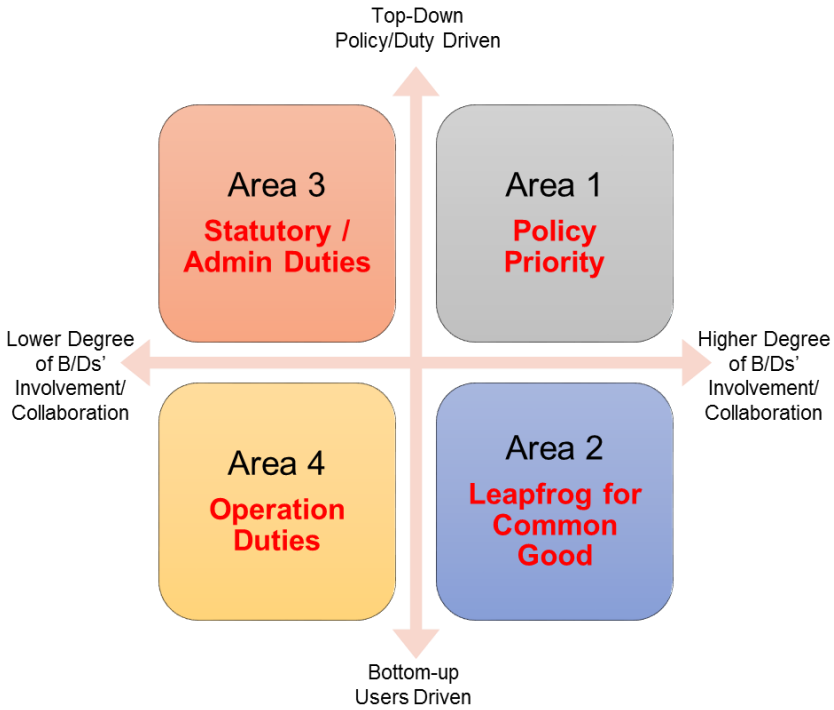


Figure 3.3 – Four-quadrant Matrix for Potential Application Types

3.2.8.5 A four-quadrant matrix (**Figure 3.3**) has been developed according to the above principles. The horizontal axis assesses the degree of involvement and collaboration of B/Ds. The vertical axis identifies the initiative of the applications, whether it is policy driven or user driven. Using the matrix, potential application types can be categorised into the following 4 areas:

- Area 1: Policy Priority – potential applications that are required by key government policy and initiatives, or as part of department's obligatory duty that involved multiple B/Ds.

- Area 2: Leapfrog for Common Good – potential applications that has common use and functionality that are demanded by multiple B/Ds. Being the same as Area 1, these are applications that require collaboration among B/Ds such as information sharing and can facilitate multiple B/Ds.
- Area 3: Statutory/ Administrative Duties – potential applications that are required by key Government policy and initiatives, or as part of department's obligatory duty of one or a couple of B/Ds.
- Area 4: Operation Duties – potential applications that would facilitate specific task or operational work of B/Ds. The applications in Area 3 and 4 might require information from other B/Ds but the application itself is only beneficial to one or a couple B/Ds.

3.2.8.6 These principles provide a selection mechanism for application development in a long run. It is anticipated that users and developers will take advantage of the BEAP environment, where common applications and data services are readily available, and develop applications in all 4 areas. While it would be easier for B/Ds to come up with application ideas for their own use under Area 3 and 4, it is encouraged to develop a good mix of applications in all 4 areas to increase collaboration and reduce duplicate effort among users.

3.2.8.7 At the initial stage, it is suggested to preliminarily focus on the applications that fall within Area 1 and 2, which collaborate and facilitate multiple B/Ds. This would allow the BEAP to get more users involved at an early stage and allow them to understand the BEAP environment quickly.

Criteria for Prioritising Potential Application Types

3.2.8.8 On the basis of the above selection principles, in order to further shortlist the most appropriate application types to demonstrate for this Study and suggest the way forward of implementing the applications in the coming years under the Application Development Plan, the following criteria are also used:

- *Application area/Topic* – fall under the 3 thematic areas: Planning & Landuse; Infrastructure & Engineering; Landscape, Environment & Conservation as specified in the Study Brief
- *Fit with the BEAP objectives* – encourage and foster high level of co-operation, collaboration and co-creation
- *Scalability* – capable to demonstrate usability in smaller scale under this study with the capacity to scale up in four different aspects in mid-long term: functionality, data, spatial coverage and user base. For example, the functions of the digital underground applications may only be demonstrated using a small area such as an NDA site with limited Government's utilities data and in the prototype stage. Subject to further investigation and availability of digitized underground utilities data, the scope of the application can be scaled up to cover the whole territory and the functionality such as clash detection and underground space volume calculation can be further developed as well as the application can also be open to non-government utilities companies.
- *Data readiness* - availability of required data and prerequisite technology maturity. For example, there are not enough real time IoT sensor available in Hong Kong to support a real-time data analysis platform that provides useful information. Similar to BIM data, most of the B/Ds only have a limited number

of BIM models which would impose constraints to their collaboration and utilization of BIM/GIS integration applications. There are other datasets that are not completely available in digital formats, which causes a deficiency of information for certain assessments such as the underground utilities, building related information such as completion year and number of dwellers in individual building.

- *New Technology* – embrace the leading-edge technology development. It is encouraged to adopt new technology such as AI and parametric design in applications to test out the capability and promote technological innovation.

3.2.8.9 With the adoption of the afore-said selection principles and evaluation criteria, the following 12 potential application types have been identified:

1. Site Search for Housing, Land and Government Facilities
   A one-stop decision making platform for B/Ds to search for sites with various selection criteria

2. Planning and Development Review and Impact Assessment (IA) Review Platform
   An integrated platform for B/Ds to upload and share their input/concerns on development plans and IA reports

3. Landuse Monitoring and Analytics, Data Update Mechanism through Artificial Intelligence (AI)
   An integrated platform for detecting any changes in landuse and abnormal activities in a designated area through AI and machine learning

4. Appraisal of Development Proposal
   An integrated platform to assist B/Ds in assessing and tendering comments on the development proposals through access to and analysis of relevant information

5. Connectivity Analysis
   A tool to identify access and routing to work, business, public amenities, neighbourhood facilities, recreational opportunities, nature, etc.

6. Scenario Generation – Development and Design Toolset
   A planning toolset to enable a quick generation of different preliminary design scheme options with input of planning parameters for scenario testing and to visualize the impacts of the design scheme on the surrounding developments

7. GIC Facilities and Open Space Analysis
   A tool to assess GIC facilities and open space with spatial dimension in accordance with the requirements of HKPSG

8. Digital Underground Space and Utilities
   An integrated platform for B/Ds to update and upkeep the record of the underground utilities with adjustable LODs as well as to facilitate forward planning for underground space

9. Visualization of Existing and Planned Development and Infrastructure Projects in Hong Kong and Greater Bay Area

An integrated platform for B/Ds to visualize existing and planned development and infrastructure projects in Hong Kong and the Greater Bay Area

10. Visualization and Analysis of Green / Blue, Socio-economic, Demographic, Conservation, Heritage, Agricultural Information
An integrated platform to visualize and analyse landscape character, green/ blue cover, vegetation density, renewable energy potential, conservation and agricultural information, historical heritage, etc.

11. City Critical Information Sharing Platform
An integrated platform to visualize and analyse the key built environment information of Hong Kong, namely socio-economic data, infrastructure projects, traffic flow survey, temperature, air quality, census data, etc.

12. Real Time IoT Analytics
An IoT application tool to enable visualization and analysis of the built environment related data collected from real-time sensors to facilitate provision of city related services

3.2.9 Synergy Workshop and Stakeholders Consultation Meeting

3.2.9.1 With the identification of 12 potential application types, a Synergy Workshop[23] with various B/Ds was held on 19 June 2018 to introduce the conceptual ideas of these application types. During the workshop, a voting had been carried out among the participant B/Ds to select the application types that were most interested in and yielded mutual benefits to them and also considered to be more imperative.

3.2.9.2 The key concerns/views solicited at the Synergy Workshop with respect to the application framework and development are summarized as below:

- Generally supports the setting-up of the BEAP to facilitate Hong Kong to catch up with the progress of smart city development around the globe and facilitate the work of B/Ds
- Generally agrees that the BEAP could be able to foster interdepartmental co-operation synergy for policy formation, decision making, resource management, efficiency, as well as the delivery of high quality services to the public
- Being positive about the application directions proposed in the Synergy Workshop which would improve efficiency, transparency and the support for decision making in planning and development
- Embraces the idea of setting up a the BEAP which can greatly expedite processing time of works among B/Ds and ensure single source of data
- More attention should be paid in the sharing of impact assessment and modelling results via the BEAP. The assumptions made must be clearly known and agreed before utilising the results in the course of undertaking various analyses

[23] Representatives from relevant B/Ds including AFCD, ASD, BD, C&SD, CAD, CEDD, DEVB, DSD, Efficiency Office, EMSD, EPD, HyD, HD, LandsD, LCSD, OGCIO, PlanD, RVD and WSD attended the workshop.

- Some of the current data may not be spatially ready or still in paper format, and thus data processing and harmonization would be required in order to transfer them into actionable data for the consumption of application development
- B/Ds are generally more interested in the bottom up user-driven applications than the top down policy-driven applications in the BEAP
- Some concerns on the release of sensitive data, which would not be suitable to share with the public or even among B/Ds

3.2.9.3 Apart from the Synergy Workshop, a Stakeholders Consultation Meeting with representatives[24] from the academia, professional institutes and organizations was held on 22 June 2018 to solicit their views on the application framework, development and associated issues. A gist of the discussion is set out below:

- The development framework should aim and promote analysis, knowledge building and application of new technologies, with an open platform and users led approach
- The integrated CSDI-BEA platform should support different building performance simulations and analyses, including but not limited to energy analysis, lighting analysis, walkability analysis, air flow analysis, etc., which are important issues in urban planning and building design
- Restrictive practices and rigid data format or standards especially those linked with specific software or organisation should be removed
- Mostly concern about the data availability and readiness in order to facilitate their own application development
- Hong Kong is lagging behind globally in terms of smart city development
- Similar to other countries and major cities, universities should play a major role in the development, operation and deployment of the CSDI which should be renamed with the participation of industries and government departments
- While the Government can kick start the initiative, academia and universities should be involved in the early stage and play a key role in both short to medium term; in fact, the success of turning Hong Kong into a smart and technology advanced city would rest with research and development outside the Government. Government departments can apply new technologies and applications as examples; however, it must be universities and the industries especially local small and medium enterprises that really make the impact

3.2.9.4 At the Stakeholders Consultation Meeting, the following scope of the application types were generally supported and were considered having potential to foster collaboration among Government departments, the academia, stakeholders and business as well as the public:

1. Walkability analysis
2. Underground utilities analysis
3. IoT smart construction
4. Building and landuse information
5. Integration of smart phone with AR/VR technology

[24] Representatives from The Hong Kong Polytechnic University, The University of Hong Kong, The Hong Kong University of Science and Technology, The Hong Kong Institute of Planners, Hong Kong Institution of Engineers and Smart City Consortium attended the meeting.

6. A single tool/platform integrating with functions of data visualization, decision making and public engagement Planning decisions tool
7. Mobility of the city
8. 3D BIM model
9. Centralized 3D/GIS information

3.2.9.5 After the Stakeholders Consultation Meeting, comments were received from academia and professional institutes highlighting the possible collaborations with the recent major research topics/findings from local research institutions/ universities and the BEAP for different application types such as walkability, environmental monitoring, landscape/greening, remote sensing, etc. Additionally, they all consider that a high degree of participation of the academia and industry in the BEAP development should be encouraged.

3.3 Technology Development Plan

3.3.1.1 The Technology Development Plan outlined the planning for the third building block of the BEAP conceptual model – the technical infrastructure.

3.3.2 Technology Infrastructure

3.3.2.1 The technology infrastructure describes the organisation of the IT infrastructure including the hardware and software platforms that the BEAP runs on and will be developed during subsequent phases of the project. The technology infrastructure required to support the BEAP will be dependent upon the division of responsibilities that are established between the BEAP, the CSDI and other enterprise initiatives.

3.3.2.2 In designing the BEAP technology architecture, the recent and rapid evolution of cloud technologies and hosted services presents opportunities that were not available when the case studies were implemented should be considered now. What we can learn from the case studies is that there has been a recent shift from hosting physical servers locally to the adoption of cloud infrastructure and cloud services.

Software Platform

3.3.2.3 There are two main aspects to the BEAP software architecture:

- The software architectures of individual built environment applications
- The software architecture of the BEAP that supports them.

Software for the BEAP

3.3.2.4 The BEAP provides the software foundations on which individual applications may be developed. These application foundations include common functions that may be used by multiple applications, such as view and query, as well as supporting functions such as user authentication and event logging. In view of the close relationship between the BEAP and the CSDI, in future, when the CSDI portal can provide all the functions required by the BEAP, the BEAP and the CSDI portal may be integrated.

3.3.2.5 Some of the software functions required to support the BEAP are identified by the AURIN logical architecture[25] as illustrated in **Figure 3.4**.

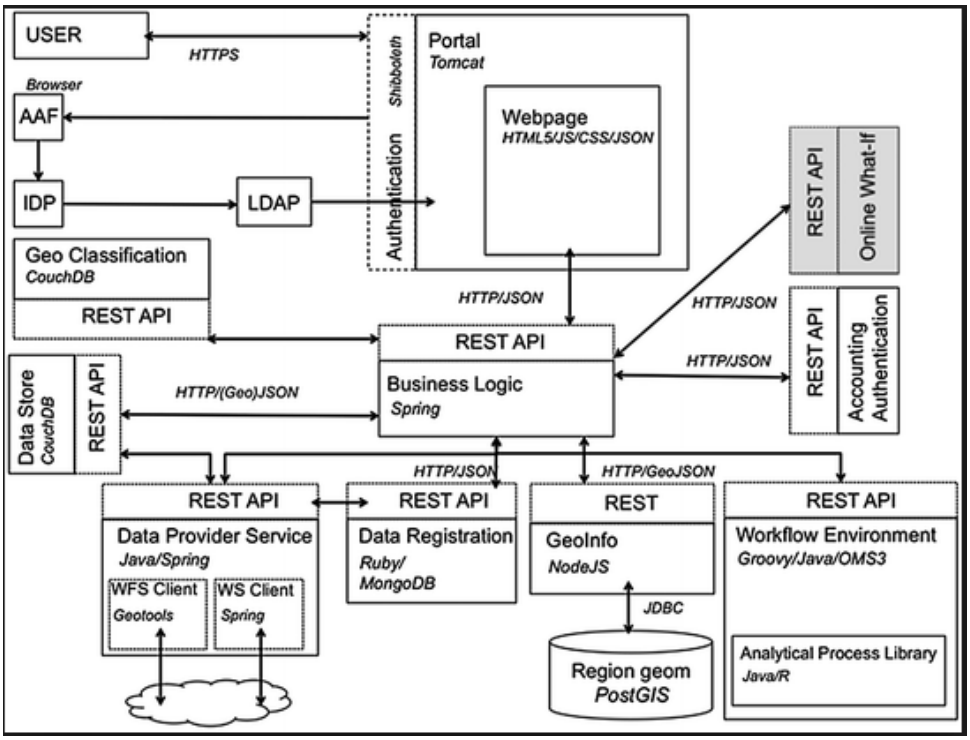


Figure 3.4 – AURIN Software Architecture Example

3.3.2.6 The AURIN software architecture diagram illustrates some of the types of software components that are used within urban information platforms. Taking this into account, the key software components of the BEAP are expected to include:

- Portal: website provides a focal point from which to discover applications and facilities, including access to actionable datasets and user collaboration tools
- User Account Management: ability to create new user accounts, manage access rights and provide user authentication.
- Catalogue query: search metadata for applications, application services, datasets, and data services

Software for individual Built Environment Applications

3.3.2.7 The BEAP will enable users to find and access the built environment applications and services. The individual built environment applications may be developed from the software components that are best suited to each application. These applications may thus be constructed in a number of ways such as:

- customizing development from scratch;
- using third party software libraries or software development kits (SDKs);

[25] https://aurin.org.au/wp-content/uploads/2014/07/AURIN-Technical-Specification.pdf

- using application services that are presented by the BEAP, or other third-party application services;
- using application functions provided by open source packages or commercial software suites; or
- a combination of the above.

3.3.2.8 The applications may be implemented in a variety of forms, including:

- Standalone desktop application
- Web application
- Web service
- Mobile application (Android, iOS)
- Embedded application

3.3.2.9 The applications may be accessed in several ways:

- Downloaded from the BEAP portal as a standalone application
- As a web application or service hosted by the BEAP
- As a web application or service hosted by a third party

Hardware Platform

3.3.2.10 The BEAP will provide a set of hosted software services that will be reside on specific servers or on cloud infrastructure, or potentially spread across both in a hybrid configuration.

3.3.2.11 The current preference of the OGCIO appears to be towards the use of cloud computing via the new GovCloud infrastructure[26]. Cloud infrastructure provides numerous advantages including improved flexibility, security and scalability, whilst reducing the administrative burden involved in maintaining local dedicated hardware environments. Pricing for cloud Infrastructure as a service should be considered to be broadly comparable with locally managed physical hardware and costs for the use of the cloud infrastructure would need to be determined as detailed needs become better defined. One of the main advantages of the cloud infrastructure is that costs can be carefully managed by being able to easily scale the cloud resources up and down as needed.

3.3.2.12 It is observed that for GeoPlatform, Portland and Virtual Singapore, the system architecture is in general designed with multiple cloud services for both applications/functions and data. Similar design approach, therefore, can be adopted by the BEAP in future.

3.3.3 Security Infrastructure

3.3.3.1 Security applies to all aspects of the BEAP design and operation, from the policies and procedures of the people working with the BEAP, right through to the physical security of the data centre(s) that host the BEAP.

- User authentication / identification

[26] https://www.ogcio.gov.hk/en/our_work/strategies/government/cloud_strategy/

- User authorisation
- Data security classification
- Data access control
- Application access control
- Digital Rights Management / data leakage
- Data aggregation (accidental insights)
- Data transmission
- Cyber/malware protection
- Network intrusion detection
- Usage auditing
- Data retention
- Backup and disaster recovery procedures
- Network and hardware security measures
- Building/facility security measures
- Technology asset disposal
- Monitoring and reporting

3.3.3.2 Whilst these considerations are not specific to the BEAP, they will need to be addressed during the design of the BEAP operating procedures, as well as during the design of applications, data management systems and technology infrastructure. The OGCIO provides guidance on the development of information security and cyber-security measures[27] within Hong Kong.

3.4 Business Development Plan

3.4.1.1 The Business Development Plan describes the services the BEAP provides to its customers and users ('Business Services'). It also considers the organisational aspects of the BEAP such as how it is staffed, managed, governed and funded ('Governance and Operating Model').

3.4.2 Business Services

Built Environment Application Curation

3.4.2.1 The BEAP will maintain a catalogue of applications that are regarded as helpful in dealing with built environment issues. The curator will actively manage this catalogue - assessing, explaining, adding and removing applications as appropriate. It is anticipated that the catalogue will serve as a gallery[28] to showcase relevant applications and provide directions to enable users to access or acquire the applications.

[27] https://www.ogcio.gov.hk/en/our_work/information_cyber_security/government/

[28] An example of an application gallery, although not specific to the built environment: https://shiny.rstudio.com/gallery/

3.4.2.2 Some of these applications may be hosted by the BEAP, others will be hosted or provided by other organisations, in which case the catalogue will direct users to the provider.

3.4.2.3 As applications are developed to address the built environment-related challenges in Hong Kong, the BEAP will enable developers to publish their applications to an application gallery where users can easily discover them. The curator may work with the developer to present their application in the most helpful manner and may decline the application if they do not believe that it is appropriate for the gallery.

Interface with Relevant Portals

3.4.2.4 As the recognised CoE for built environment applications, the BEAP will be well equipped to support the CSDI for dissemination and sharing of spatial data and align with the data specifications and standard developed under the CSDI. Data standards ensure that data can be used interoperably such that data created within one system for one purpose can be interpreted unambiguously so that it may be used confidently elsewhere for other purposes, such as the CSDI and the PSI portal (data.gov.hk). Data standards are essential in enabling data to be reused, thus enabling operational efficiencies and avoiding duplication of effort and risk of confusion.

3.4.2.5 Data models for urban environments are expected to become increasingly rich and complex to enable problems to be solved in new and innovative ways[29]. The BEAP can serve to contribute to the development of local data standards to enable interoperability and collaboration and could serve to represent Hong Kong's interests externally in the development of regional and international standards[30].

Evaluation on Effectiveness / Performance of BEAP Applications

3.4.2.6 It is necessary to have regular evaluation on the effectiveness/performance of the applications in order to foster continuous improvements and evolution of the BEAP. Below is the list of suggested attributes for the evaluation of the applications.

- Usage rate of the application and actionable data
- Number of external parties involved in developing applications
- Ease of access of functions
- Loading time of the application (e.g. visualization of 3D map for mobile, web and desktop users)
- Ease of information searching and downloading
- End user experience in visualization of data / analysis results
- Functionality performance of applications

[29] http://www.urbantransformations.ox.ac.uk/blog/2017/shaping-data-standards-for-future-cities/

[30] http://citiscope.org/story/2017/how-iso-standards-city-data-are-starting-make-impact

3.4.3 Governance and Operating Model

3.4.3.1 The Governance and Operating model describes how the BEAP is structured and how it organises its resources to deliver its services.

High Level Operating Model

3.4.3.2 Based on the positive experiences of cities such as Singapore and Portland, it is recommended that the BEAP is established as a permanent corporate function of dedicated staff with relevant expertise. Other cities have demonstrated how a small team of experts can function very efficiently in delivering specialist applications and in supporting users in their adoption.

3.4.3.3 Non-core functions should be divested so that the team can concentrate on the activities that provide the most value. In establishing the BEAP, it is anticipated that third party application developers and system integrators will be contracted to reduce the time to build the BEAP. Afterwards it is expected that the BEAP application development team will maintain the applications and develop new ones.

3.4.3.4 It is further recommended that the BEAP follow a collaborative approach in which its dedicated team of domain specialists would be supported by partners from the business, academia and indeed the public, who could in turn develop applications for use within the BEAP.

Dedicated Team for the Operation and Management of the BEAP

3.4.3.5 In order to ensure a smooth operation and management, the BEAP will require a dedicated team subject to the leadership and governance of the CSDI to deliver the services and manage the platform. The responsibilities of the team would cover the followings to oversee the development and operation of the BEAP:

- Developing new BEAP applications and application services, which would be supported by Solution Architects, Business Analysts, Application Developers and Testers with participation of users.
- Processing actionable data (information products) to support the needs of built environment professionals and consists of Spatial Data Analysts, Data Modellers and Spatial Data Engineers.
- Ensuring smooth running of the BEAP hardware and software infrastructure which would be supported by Server Administrators, Database Administrators and Security professionals.
- Fostering cross B/Ds' coordination and collaboration with stakeholders, academic and relevant parties to facilitate the development, alignment and integration of various built-environment applications and to create synergy and ecosystem to take forward the development of the BEAP.

End-user engagement and training framework

3.4.3.6 A key success criteria for the BEAP is likely to be uptake by users. A user engagement and training framework will be required to ensure that end users can get the most out of the platform and its applications. This task should not be underestimated either in scope or importance. **Table 3.2** shows at a high level the

types of activity that might be required to develop and implement a user engagement and training framework.

Activity	Description	Outcome
User engagement and training framework development	Developing a framework outlining what needs to be uncovered from the stakeholder / user community (e.g. what do they need/want from the BEAP, barriers & blockers to use, user perception, general organisational readiness for the BEAP) This will help to address / define business change activities – particularly training	• User engagement and training framework with key areas & questions
User engagement	Application of the framework through engagement with users including: - User needs analysis - Technology readiness survey - Skills gap analysis	• User needs survey outputs • Technology readiness survey outputs • High level training requirements
Analysis	Assess the information gathered to define the activities required from further engagement and training	• Training Needs Analysis • Training Plan
Implementation	Develop and deliver training courses and resources – some may be face to face, others to be online (e.g. video tutorials)	• Training modules and resources • Training delivery
Continuous user group engagement	Ongoing engagement with user groups to ensure any problems are addressed early and swiftly (moving to a BAU role)	• Continuous involvement of staff (ensuring user buy-in)

Table 3.2 – Types of High Level Activities for User Engagement and Training Framework

3.5 Implementation Plan

3.5.1.1 The key implementation milestones of each building block from short to long term are summarized in **Table 3.3**:

	Short Term	Mid to Long Term
Overall	• Develop the BEAP in cloud environment	• The BEAP with an increased number of applications, actionable data and supporting functions covering the areas of

	Short Term	Mid to Long Term
	• Implement the recommended applications as quick-win projects • Initiate an eco-system and incentives for more Government agencies, business and academia to collaborate on application development as the value of applications are being demonstrated • Set up a BEAP team to manage and lead the foundation of the BEAP • The BEAP is mainly for internal users (i.e. relevant B/Ds) • Directly link the BEAP to the CSDI	Planning & Landuse, Engineering & Infrastructure and Landscape, Environment and Conservation • The BEAP Team continues to develop the ecosystem and drive the BEAP development • The BEAP to be opened for both internal and external users • The BEAP with a city-wide/cross-sectorial applications, actionable data and supporting functions • Establish a mature eco-system and partnerships / engagement models with both internal (i.e. Government B/Ds) and external (i.e. business, academia, and the public, etc.) parties
Application and Actionable Data	• On the basis of the recommendations of this Study to take forward the suitable applications as quick-win project in short term • Collaborate with B/Ds to implement planning and development related applications • Enrich the BEAP actionable data and new actionable data sets generated from applications	• Strengthen (e.g. more functions) and widen (e.g. scale up to other regions) the applications in the area of planning and development • Develop new applications in areas covering Planning & Landuse, Engineering & Infrastructure and Landscape, Environment and Conservation • Foster a growing community of application developers with both inter-Governmental and external collaboration • Enhance preliminary APIs for applications, to enable and encourage third party (business, academia and the public) to apply their ideas to develop new applications

	Short Term	Mid to Long Term
	• Initiate preliminary APIs for applications • Explore possible collaboration with the business, academia, and the public	• Increase number of applications being developed and made available for the business, academia and the public • The availability and richness of APIs for application gradually become more mature with more platform functionality
Technology	• Set up a BEAP Team by following the structure of the BEAP conceptual model • Provide software infrastructure, including security infrastructure sufficient to cover the applications and actionable data developed • Review supporting software packages to advise appropriate packages for the BEAP	• Implement the main phase of construction of the BEAP • Establish the core software packages and hardware infrastructures to cope with the increasing number of applications • Encourage the use of open-source software packages • Establish the security infrastructure at every level to enable different user access levels
Business and Governance	• Set up a BEAP Team to manage and lead the foundation of the BEAP • Take forward high level and detailed designs/ plans for the BEAP and the prioritized applications as quick-win projects • Prepare and run tenders for implementation support, platform	• The BEAP Team continues to develop ecosystem to foster collaboration among B/Ds, business, academia and the public, as well as to drive the BEAP development • Review legal framework and establish legal basis • Develop business change strategy, including adoption, training and communication plans • Provide incentives to promote the use of the BEAP • Set out the criteria for future applications to be put under the BEAP to ensure quality of services • In parallel with work being done under CSDSC, CSDI DAWG and DTSWG,

	Short Term	Mid to Long Term
	build, hardware, software, etc. • Liaise with the CSDSC, CSDI DAWG and DTSWG on matters relating to the development of the BEAP and the CSDI as well as the data and technical standards to ensure alignment among each other • Interface and link up the BEAP with the CSDI under the same single portal (i.e. the CSDI portal)	study the approach of interfacing with the CSDI to ensure proper interfacing where needed • Ongoing customer engagement, extending to the business, academia and the public • With the anticipated increase in engagement with Government agencies, academia and the wider community in the development of various applications, the strength and skill requirements of the BEAP team may be due for review

Table 3.3 – Key Implementation Milestones of Each Building Block from Short to Long Term

3.6 Relationship between the BEAP and CSDI

3.6.1.1 Upon implementation of CSDI portal in Hong Kong, it is assumed that CSDI would become the main access route to spatial data to be shared by Government data producers.

3.6.1.2 CSDI would provide a general-purpose access mechanism to incorporate spatial data and BEAP would add value for built environment professionals by presenting a set of applications, actionable data and services that consume data from the CSDI portal. In addition, the Business Services of the BEAP will be incorporated into that of the CSDI, while the BEAP portal will be interfaced with the CSDI portal, as such, the common applications in the BEAP would be linked with and accessed through the CSDI portal.

3.6.1.3 According to the conceptual operating model of the CSDI platform based on the recommendations of the CSDI Study[31] commissioned by DEVB (**Figure 3.5)**, it is anticipated that the BEAP would be one of a number of application platforms (or suites of applications) – as indicated on the far left of the diagram – that have been developed and shared by individual B/Ds, and which access spatial data through CSDI. The common BEAP applications and/or other B/Ds' specific business application which are shared with other departments will have linkage to the CSDI portal, while the less common built-environment applications can be searched through the Catalogue Services under the BEAP. It is envisioned that all the required data to support the BEAP and its applications will be sourced directly from

[31] Please refer to Figure ES4 on page 7 of the Executive Summary of Consultancy Study on Development Strategy of a Common Spatial Data Infrastructure.

the CSDI while some data collected from CSDI may need to be further modelled/processed to suit the application development. It should be noted that the data, if considered discoverable and/or sharable under the BEAP, will be fed to the CSDI portal for sharing and dissemination among B/Ds or for public consumption.

3.6.1.4 Upon the endorsement of the CSDSC, the common applications of the BEAP would be linked to the CSDI portal and operate like a "kitchen" using the ingredients from the "market" (the CSDI) for developing various built-environment related and innovative applications, by tapping the data and services in the CSDI (which is akin to a one-stop data "supermarket" in operation mode), to make the raw materials become value-added solutions for shared use among B/Ds, facilitating and promoting smart governance, and in a wider context to enable co-creation with business sector, academia and the public. More importantly, the BEAP would create an eco-system with the use of different technologies and applications such as BIM, remote sensing, data analytics, machine learning, scientific modelling and other geospatial systems, where B/Ds, academia, professionals, business and different sectors of the community can co-operate, collaborate and co-create under the atmosphere, creating synergy effects and boosting up the usage and benefits of the CSDI.

3.6.1.5 It might be anticipated that other platforms similar to the BEAP may be developed to address the specific needs of other interest groups such as health[32], transport, law enforcement and social care. Each interest group is likely to access to shared spatial data to address different sets of problems – each requiring different views of the data or differing levels of detail. Social care applications, for example, may require personal data on individuals to be collated from multiple sources (e.g. schools, police, social services, hospitals, etc.) to present a joined-up view of the circumstances relevant to their applications. Although personal data may be required, they are not intended to be stored. Whilst there may be a spatial dimension to that data, much of it would be of little or no direct relevance to the built environment applications and therefore is better suited to being presented via a different application platform. Having said that, the relevance and use of data from different themes, such as health, transport and social care, etc. should not be ruled out in the course of developing applications under the BEAP from the CSDI perspective.

[32] An example of an application platform for Health https://spatialdata.dhsprogram.com/home/

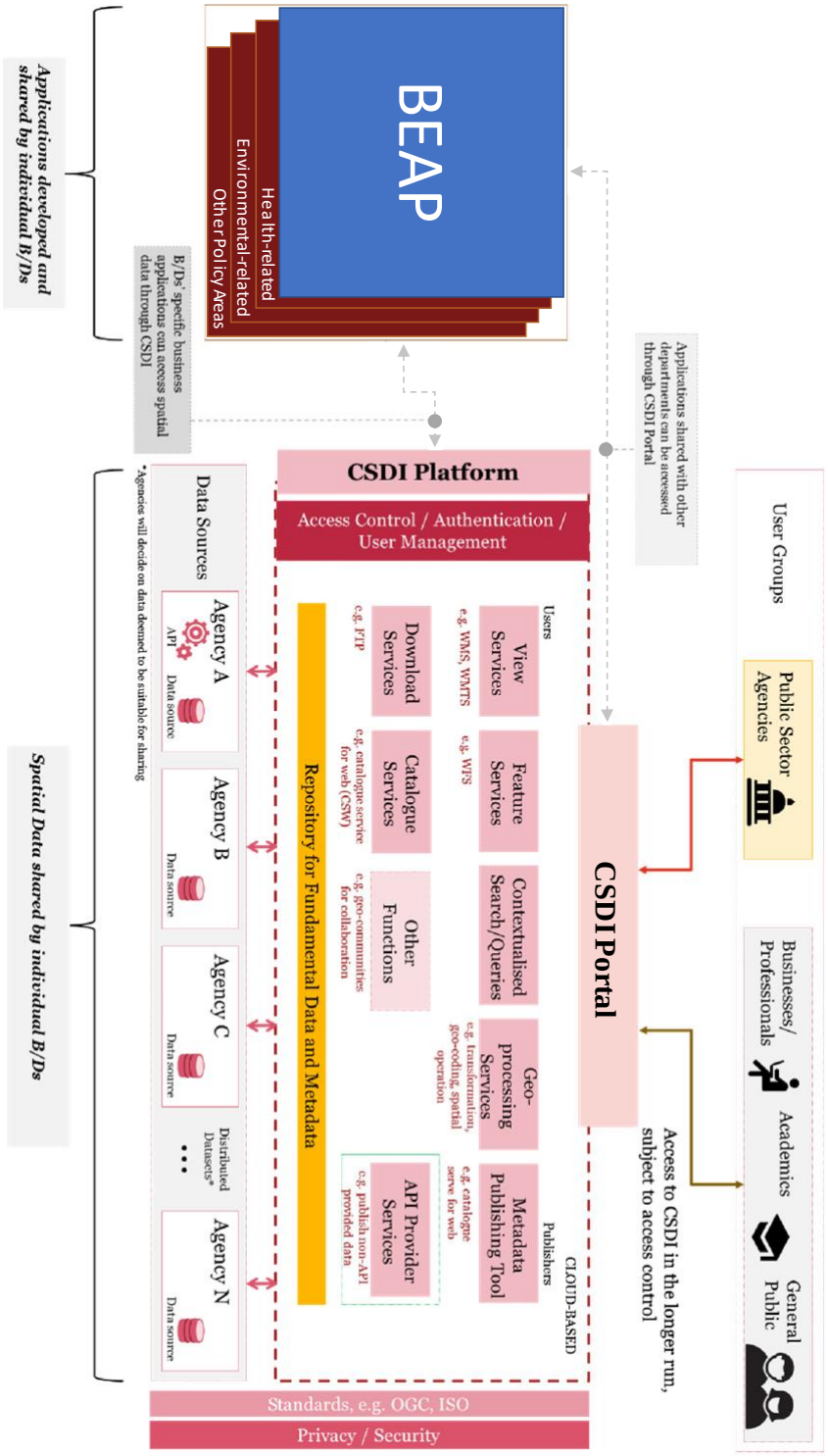


Figure 3.5 – Conceptual Operating Model of the BEAP and the CSDI

4 DEVELOPMENT OF THE PROOF OF CONCEPT AND PROTOTYPES OF THE TEST CASE FOR BEAP

4.1 Stage 1 – Identification of Potential Application Types for Development of PoCs and Prototyping

4.1.1.1 In Stage 1 of the Study, 30 application types were identified and consolidated to set out the direction for development of proof of concepts of the test case for the BEAP. Besides, a set of criteria and principles has also been derived to identify, select and accord priority to the potential application types. Based on the pre-defined criteria and principles, 12 potential application types, under thematic areas covering planning and landuse, infrastructure, engineering, and landscape, environment and conservation and others have been discussed at the Synergy Workshop and Stakeholders' Consultation Meeting for further investigation in Stage 2 of the Study.

4.2 Stage 2 – Recommendation of Proof of Concept of Test Case for the BEAP

4.2.1 30 Proof of Concepts of Test Case for the BEAP

4.2.1.1 In Stage 2 of the Study, based on the potential application types identified in Stage 1, further discussion with different B/Ds including HyD, WSD, LCSD, GLTMS, DSD, CEDD, EPD, AFCD, OGCIO, TD, BD, ArchSD, etc. and internal reviews have been conducted to explore the feasibility of further development of the identified application types. Taking into account the underlying principles including benefits to more users, user-oriented and policy-driven, scalability and data readiness, 30 application types are identified for development of PoCs, 10 out of which are selected for further development as prototype applications. **Figure 4.1** shows the process of identifying of 30 PoCs and 10 prototypes.

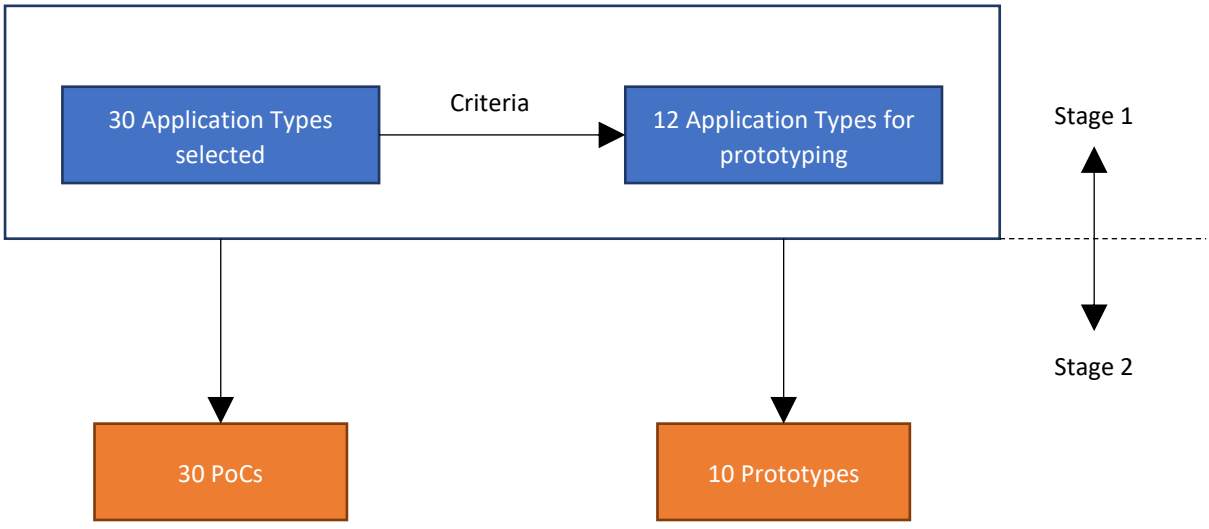


Figure 4.1 – Process of Identification of 30 PoCs with 10 Prototypes of the Test Case for BEAP

4.2.1.2 A list of 30 PoCs under different thematic areas (i.e. (i) Planning and Landuse; (ii) Infrastructure and Engineering; (iii) Landscape, Environment and Conservation; (iv) Others), in which 10 are identified as prototypes under the Study are shown below:

Planning and Landuse

(1) Landuse Monitoring and Analytics*
(2) Site Search*
(3) Scenario Generation for Planning and Development*
(4) GIC Facilities and Open Space Analysis*
(5) Connectivity Analysis*
(6) Preliminary Technical Review – Traffic
(7) Preliminary Technical Review – Hazard
(8) Parametric Toolkits for Masterplan Evaluation
(9) Urban Renewal Assessment Tool
(10) Development Tool for Visualization of Government Information in AR/VR Environment
(11) e-Engagement Tool

Infrastructure and Engineering

(12) Visualization and Analysis of Underground Space and Utilities*
(13) Visualization of Existing and Planned Development and Infrastructure Projects
(14) Preliminary Technical Checking – Sewage
(15) Preliminary Technical Review – Drainage
(16) Compliance Checking of Building Plans*
(17) Work Site Inspection (Engineering)
(18) Work Site Inspection (Site Safety)
(19) 3D Visualization of Existing and Planned Developments using AR/VR

Landscape, Environment and Conservation

(20) Visualization and Analysis of Urban Green Infrastructure*
(21) Preliminary Technical Review – Noise
(22) Preliminary Technical Review – Air Quality
(23) Preliminary Technical Checking – Air Ventilation
(24) Work Site Inspection (Environmental Compliance)
(25) Assessment on Green and Blue Provision
(26) Community Resilience to Climate Change

Others

(27) Built Environment Information Dashboard*
(28) Workflow Management Platform*
(29) Automatic Notification of Data Updating
(30) City Management Tool

* *Selected for further development of prototype applications*

4.2.1.3 A summary of the objectives and functions of each PoC is shown below. For details of each PoC, please refer to the "Final Interim Report on the Development of Proof-of-Concept and Prototypes of the Test Case for BEAP".

Planning and Landuse

Applications	Objectives/Functions
1. Landuse Monitoring and Analytics*	- The Government has been facing challenges on how to effectively detect landuse changes from time to time to identify possible illegal activities and unauthorized development. The application is an integrated platform for stockpiling multi-source, -level and -date images, which can be accessed and visualized by users, as well as facilitating landuse classification and detection of land cover change with the aid of AI technology. - The application adopts the integrated approach for collecting image data from 'space', 'sky' and 'land', which are referred to satellite images, aerial photographs, images captured by UAVs, site photos and scanned images taken by moving vehicles, to enhance the accuracy of the methodology in undertaking landuse classification and detection of land cover/height level change.
2. Site Search*	- During planning and design stage of developments, B/Ds often have to undergo an initial screening exercise to identify the potential suitable sites to meet their specific purpose based on pre-defined searching criteria. Under current practice, PlanD would initiate the site search exercise upon the B/Ds' request. - The application aims to revamp the existing site search tool with incorporation of advanced GIS technology and additional criteria to enhance the efficiency and accuracy of the searching results, and to provide a one-stop web-based platform to facilitate B/Ds to submit site search requests. - Key functions include developing a web-based platform for B/Ds to input required site parameters and submit site search requests to PlanD; performing suitability analysis to find out the suitable site of different locations for accommodating specific landuse by factoring in various selection criteria; visualizing site search results via an interactive GIS platform in 2D/3D environment; retrieving the current and previous site search records for comparison and prioritizing results with weighting of different searching criteria.
3. Scenario Generation for Planning and Development*	- To facilitate landuse planning, a scenario generation tool has been developed that allows users to generate a preliminary landuse scheme (with building massing) in 3D environment for NDAs or a particular area based on the pre-defined development parameters - The application embraces functions to modify the development schemes and visualize the instant results upon alteration in development parameters such as plot ratio, number of building blocks or floors, etc. and to conduct compliance checking of the proposed schemes against relevant planning and building guidelines/regulations.
4. GIC Facilities and Open Space Analysis*	- The provision of GIC facilities and open space is based on various factors. HKPSG has set out a criteria for determining the scale, location and site requirements of various landuses and facilities.

Applications	Objectives/Functions
	- The application provides a tool to easily assess the provision requirements of GIC facilities and open space at district or New Development Area and to visualize spatial distributions of community facilities and open space via the web-based map interface. - Key functions include generating a summary of table showing the existing and planned various GIC facilities and open space based on the input of the population projection in an area and the provision requirements as stipulated in the HKPSG, displaying spatial location of GIC facilities and open space with supplementary detailed information, and conducting service area analysis of GIC facilities and open space, which provides an overview of the extent of services coverage of the facilities and open spaces to facilitate decision-making in particular for planning of new GIC facilities and open spaces.
5. Connectivity Analysis*	- The importance of pedestrian-oriented development has been well recognized by the Government in improving and reinforcing city attractiveness and citizen well-being. - The application provides a common platform to display the pedestrian network connection and associated facilities in 2D/3D environment, conduct walkability analysis to enhance the pedestrian environment and landuse planning, and to encourage sharing practices and research results from the academia or other organisations to promote walkability in the community.
6. Preliminary Technical Review – Traffic	- A web GIS-based traffic impact review tool to share and examine preliminary results of traffic impact on the proposed developments initiated by B/Ds. - Upload and archive the assessment results for viewing among B/Ds. - Workflow management tool to facilitate B/Ds to tender comments on the development proposals.
7. Preliminary Technical Review – Hazard	- A web GIS-based hazard impact review tool to share and examine any potential risk impacts arising from PHIs on the proposed developments initiated by B/Ds. - Upload and archive the assessment results for viewing among B/Ds. - Workflow management tool to facilitate B/Ds to tender comments on the development proposals.
8. Parametric Toolkits for Masterplan Evaluation	- An interdisciplinary parametric analytical tool to evaluate the possible outcomes of different urban development scenarios with a suite of cross disciplinary assessment tools to estimate the technical impacts in terms of traffic, noise, air, drainage and sewage, etc. of the planned development. - Provide toolset to guide the design of conceptual masterplans through high-level analytical insights and help steer the planning design process.

Applications	Objectives/Functions
9. Urban Renewal Assessment Tool	- An upgrade of the existing PlanD's Development Intensity (DEVIN) Model, which is a computerised model to estimate likely future levels of redevelopment in existing urban area. - Simulate the redevelopment process and assess the redevelopment potential on land occupied by existing buildings with due regard to financial viability, the provision of GIC facilities and open space, environmental and other socio-economic factors. - Assign and adjust the weight of different factors including intangible environment and socio-economic factors according to the preference for estimation of redevelopment potential - Compare the redevelopment potential of various sites.
10. Development Tool for Visualization of Government Information in AR/VR Environment	- A development tool for B/Ds to build AR/VR models of potential/planned developments to facilitate engagement activities to solicit the public comments on the development proposals or planning studies. - Provide a library of AR/VR model e.g. infrastructure, building block, street furniture, etc. to enable quick formulation of engagement tools.
11. e-Engagement Tool	- Provide e-template or tools for B/Ds to design the internet web-based application for public engagement purpose by using the portal design interface. - Facilitate collection of web-based feedback and undertaking of on-line questionnaire/survey to collect public views on the specific projects. - Automate result analysis of the feedback received.

Infrastructure and Engineering

Applications	Purpose/Functions
12. Visualization and Analysis of Underground Space and Utilities*	- Hong Kong has encountered land supply shortage problems for years and thus making good use of underground space could help relieve the pressure of land supply. - The application integrates relevant information to produce an interactive 3D underground space and utilities platform that visualizes the existing underground space development, structure and utility network, etc., to assist the Government B/Ds in underground space planning through identification and visualization of various possible constraints, and to facilitate underground utilities planning and checking.
13. Visualization of Existing and Planned Development and Infrastructure Projects	- Provide a web-based GIS platform for government users to visualize all the information relating to infrastructure and public works project with general statistical data on the planning and infrastructure matters in Hong Kong and nearby regions. - Provide analytical and searching functions such as travel distance measurement. - Overlaying of geographical statistics and spatial data at city level - Easy export of statistical and analytical results in different

Applications	Purpose/Functions
	formats.
14. Preliminary Technical Checking – Sewage	- A web GIS-based tool to provide preliminary checking on the service capacity of existing sewage treatment facilities and pumping station based on development proposals initiated by B/Ds and population density, identify facilities that requires upgrade work. - Upload and archive the assessment results for viewing among B/Ds. - Workflow management tool to facilitate B/Ds to tender comments on the development proposals.
15. Preliminary Technical Review – Drainage	- A web GIS-based drainage impact review tool to share and examine preliminary results of drainage impact on the proposed developments initiated by B/Ds. - Upload and archive the assessment results for viewing among B/Ds. - Workflow management tool to facilitate B/Ds to tender comments on the development proposals.
16. Compliance Checking of Building Plans*	- Visualize the proposed developments in 3D environment. - Extract the necessary data automatically from the BIM projects for compliance checking against the prevailing regulations such as statutory planning and fire safety requirements. - Give alert to potential violation of guidelines/requirements - Enhance compliance checking process and save time in manual checking.
17. Work Site Inspection (Engineering)	- A tool for B/Ds to gain access to site information captured through CCTV cameras and other video capture equipment to help conduct site inspection. - Monitor the progress of the works and check against site inspection requirements such as the required no. of workers and the construction sequence, etc. with the aid of machine learning, video analytics and artificial intelligence. - Upload site inspection information e.g. site photos, video, inspection forms, etc. and allow data sharing among B/Ds via the platform.
18. Work Site Inspection (Site Safety)	- A tool for B/Ds to monitor the conditions of work sites and actions of site workers to minimize number of site accidents through the installation of CCTV cameras and other video capture equipment. - Detect any violation of safety regulations/measures with the aid of machine learning, video analytics and artificial intelligence. - Upload site inspection information e.g. site photos, video, inspection forms, etc. and allow data sharing among B/Ds via the platform.
19. 3D Visualization of	- AR/VR tools for B/Ds to easily visualize and comprehend the existing and planned development projects including the internal

Applications	Purpose/Functions
Existing and Planned Developments using AR/VR	and external structures, underground pipes or utilities with real world data as background. - Provide functions of generating animation such as pedestrian, traffic, flight or walk modes in the AR/VR environment. - Integrate other 3D data to enable full understanding of future experience.

Landscape, Environment and Conservation

Applications	Purpose/Functions
20. Visualization and Analysis of Urban Green Infrastructure*	- In a high-rise and compact city like Hong Kong, the green and blue assets[33] would be the essential components to make our city become livable and sustainable. To take forward the development of functional green infrastructures in Hong Kong, the application is tasked to provide a web-based common platform for visualizing green-related information, academic research results of green-related indices with a view to supplementing more information to facilitate making informed decision in the course of built environment planning. - Key functions include collecting and collating different green/blue data in urban area from various sources; visualizing green-related information and academic research results of green-related indices which would serve as reference or supplementary materials in the course of built environment planning and performing shadow analysis to allow users to calculate the shadow ratio of a selected area to facilitate local/district planning.
21. Preliminary Technical Review – Noise	- A web GIS-based noise impact review tool designed to share and examine preliminary results of noise impact of proposed developments initiated by B/Ds. - Upload and archive the assessment results for viewing among B/Ds. - Workflow management tool to facilitate B/Ds to tender comments on the development proposals.
22. Preliminary Technical Review – Air quality	- A web GIS-based air quality impact review tool designed to share and examine preliminary results of air impact on the proposed developments initiated by B/Ds. - Upload and archive the assessment results for viewing among B/Ds. - Workflow management tool to facilitate B/Ds to tender comments on the development proposals.
23. Preliminary Technical Checking – Air ventilation	- A web GIS-based air ventilation impact review tool to share and examine the preliminary results of air ventilation impact on the proposed developments initiated by B/Ds results.

[33] Green and blue assets generally refer to urban infrastructure relating to vegetation and water.

Applications	Purpose/Functions
	- Upload and archive the assessment results for viewing among B/Ds. - Workflow management tool to facilitate B/Ds to tender comments on the development proposals.
24. Work Site Inspection (Environmental Compliance)	- A tool to assist in performing environmental compliance checking including air quality, noise, waste and water pollution aspects during the construction stage through the installation of CCTV cameras and other video capture equipment. - Monitor whether the construction site would violate environmental protection requirements with the aid of machine learning, video analytics and artificial intelligence. - Upload site inspection information e.g. site photos, video, inspection forms, etc and allow data sharing among B/Ds via the platform.
25. Checking of Green and Blue Infrastructure Provision	- A tool to visualize the existing and planned green and blue infrastructure in 2D/3D environment. - Assess the requirement of green and blue infrastructure for the area with the support of green and blue facilities database (including community gardens, open space, water sensitive urban design features, green rooves and walls, bike paths and trails). - Conduct preliminary assessment to compare benefit and cost saving of the different green and blue infrastructure.
26. Community Resilience to Climate Change	- A scaled-up tool to enrich the functions of the Common Operational Picture (COP) platform which was set up under Hong Kong's Climate Action Plan 2030+ to enhance a smart reaction to major disasters in 2017. - Extract relevant emergency information for dealing with hazards under extreme weather events such as the identification of district-based resources centres and the locations of GIC facilities (i.e. community centres, schools, sports centres, etc.) for visualization and analysis in 2D/3D environment. - Provide a function of cross-referencing other spatial and non-spatial data on top of the extracted information from COP database to facilitate undertaking resilience planning so as to reduce future disaster risk by improving provision of infrastructure and GIC facilities.

Others

Applications	Purpose/Functions
27. Built Environment Information Dashboard*	- Although some Government websites, such as the GeoInfo Map, Hong Kong GeoData Store and MyGovHK are available for the public to comprehend a wide range of city data, there is a lack of a dedicated platform for browsing the built environment related information, which would be of the public interest in particular for application development.

	- The application not only serves as a landing page to access to all the BEAP applications, but also provides a common platform with a map interface that displays built-environment related data and KPIs in dashboard format based on information/data gathered from the BEAP applications, namely the vegetation cover and the buildings with different age in district level. Through the platform, the users are also able to customize the information including the legends and the content of the KPIs to be displayed as well as perform data correlation analysis by selecting preferred data from a repository of the datasets such as the relationship between building and population age.
28. Workflow Management Platform*	- There are a number of consultancy studies commenced every year to provide expertise data/information, technical solutions, analyses, etc. to facilitate informed policy decision making. The study briefs and related tender documents of these consultancy studies are often required to be circulated among various B/Ds with professional disciplines for their input and advice and the process involved would be time-consuming and tedious. - To streamline the whole circulation process, the application provides a collaborative platform to establish workflow management for different B/Ds to tender their comments/advice on the draft study brief of the consultancy studies. Through the platform, the users are able to gain access to the previous briefs/tender documents of various projects/studies and other relevant information for reference.
29. Automatic Notification of Data Updating	- Automate notification to relevant B/Ds users once the data being adopted in the built-environment applications has been updated in the BEAP. - The updated data, if become sharable and discoverable, can be fed to the CSDI portal for dissemination and sharing among B/Ds or the public.
30. City Management Tool	- There are many different sub-systems e.g. waste, climate, energy management, etc. concurrently in operation, but running in a silo. - Establish a city operation platform adapting virtual twin technologies, cloud computing, big data, data management technologies, etc. to visualize and manage different city sub-systems in one single application for multiple types of users to enhance operation efficiency across various domains. - Collect city/district level data from various sources and mapped in the virtual twin of city with personalised dashboards, which can be used for further analyses with other applications in BEAP.

Remarks: * Selected for further development of prototype application.

4.2.2 10 Prototypes of Test Case for BEAP

4.2.2.1 10 out of the 30 identified applications have been selected for further development of prototypes, where prototypes are the sample versions of the applications developed to demonstrate the capabilities and feasibility of the full implementation of each application

10 Prototypes of Test Case

4.2.2.2 The following is the 10 prototype applications of test case for BEAP (**Figure 4.2**):

(1) Landuse Monitoring and Analytics
(2) Site Search
(3) Scenario Generation for Planning and Development
(4) GIC Facilities and Open Space Analysis
(5) Connectivity Analysis
(6) Visualization and Analysis of Underground Space and Utilities
(7) Compliance Checking of Building Plans
(8) Visualization and Analysis of Urban Green Infrastructure
(9) Built Environment Information Dashboard
(10) Workflow Management Platform

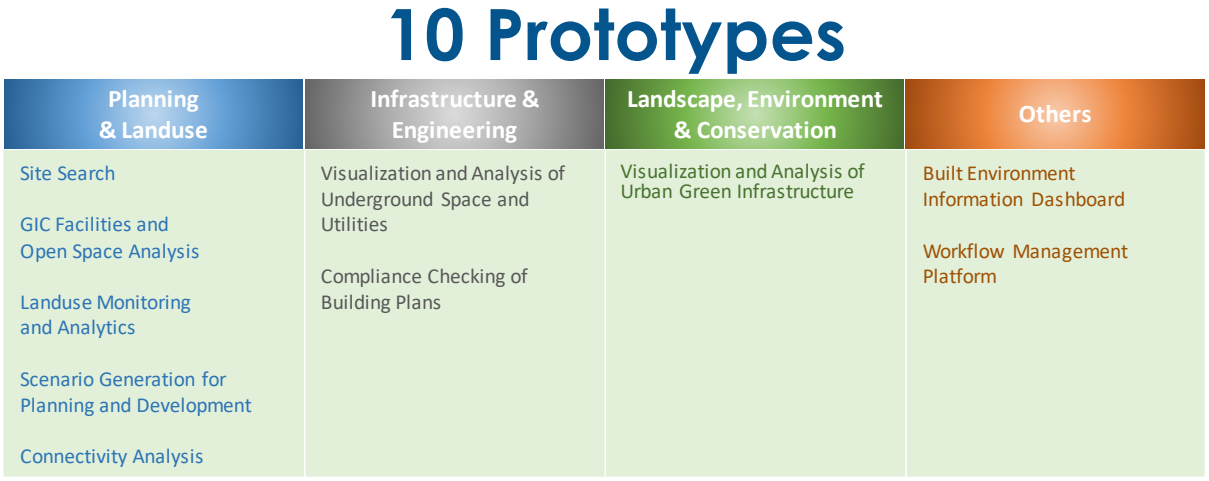


Figure 4.2 – 10 Prototype Applications under the Four Thematic Areas

4.2.3 Demonstration Sessions in Stage 2

4.2.3.1 To facilitate soliciting feedbacks and advice from B/Ds, two demonstration sessions were held on 26 June and 26 July 2019 respectively to brief the scope and key functions of each prototype.

4.2.3.2 The 1st demonstration session covered four prototypes (i.e. Site Search, GIC Facilities and Open Space Analysis, Scenario Generation for Planning and Development and Connectivity Analysis) whilst the 2nd demonstration session covered the remaining six prototypes (i.e. Landuse Monitoring and Analytics, Visualization and Analysis of Underground Space and Utilities, Compliance Checking of Building Plans, Visualization and Analysis of Urban Green Infrastructure, Built Environment Information Dashboard and Workflow Management Platform).

4.2.4 Application Development – From Prototyping to Implementation

4.2.4.1 In the course of the prototype development, close liaison and working meetings were held with various B/Ds, academia and other relevant parties to have a grasp on their concerns and seek for their views on the scope and functions of the prototypes. The standard functions were then defined based on the views collected from relevant stakeholders and lessons learnt during prototype development.

2.1.5.4 For future implementation of these prototype application, it is envisaged that standard functions would need to be further strengthened in the following two different dimensions (**Figure 4.3**):

- Depth – Further deepening of current functions through the incorporation of more data and more comprehensive analysis; and
- Width – Provision of a wider range of coverage of the functions, from the testing area to potentially the entire territory.

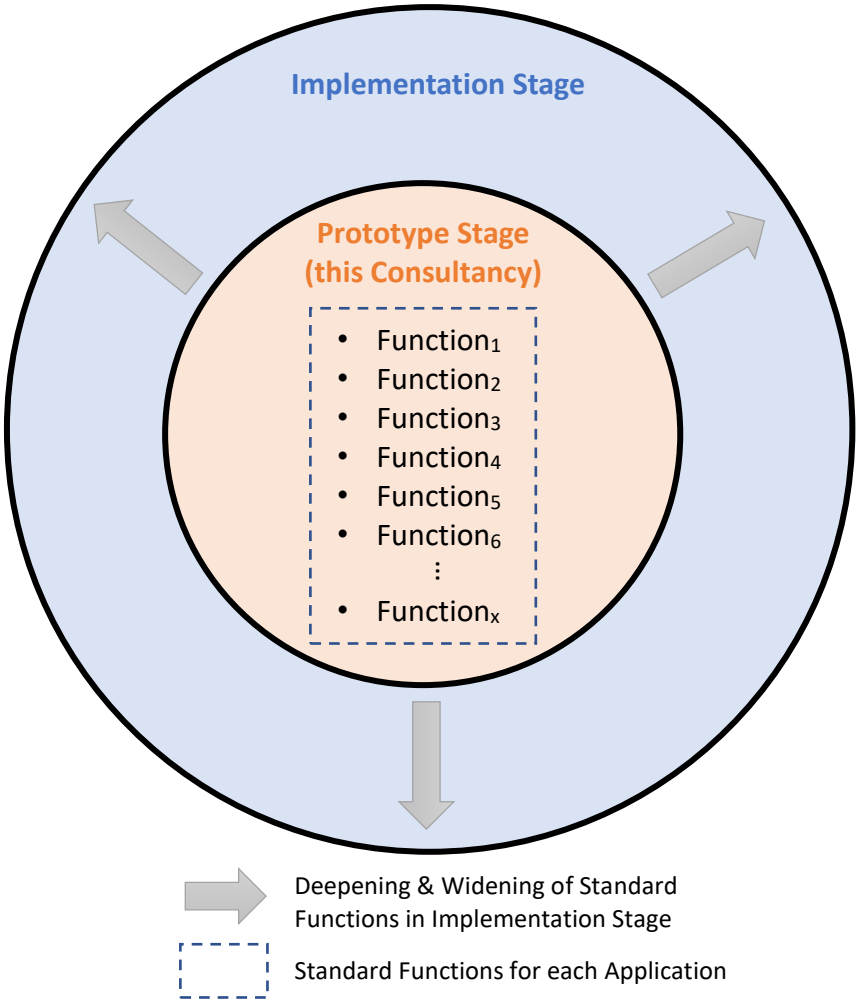


Figure 4.3 – Application Development from Prototyping to Implementation Stage

4.2.5 10 Prototype Applications

4.2.5.1 The ensuing sections would provide general description on each prototype application, which covers the following aspects:

- Background: To state key facts, background information, challenges and constraints being faced, and current approach and workflow.
- Purpose: To describe the objectives and scope of the prototype applications.
- Benefits: To highlight how the prototype application can improve the workflow and efficiency of different parties involved.
- System Design: To outline the overall system architecture, development and workflow of the full extent and potential of each application.
- Study Area: To depict the coverage or extent of each prototype application.
- Functions: To provide an overview of each function of each application. The functions delivered in the prototype stage is based on the data gathered from different B/Ds and relevant parties. It should also be highlighted that the success of the proposed functions hinge on the availability of required data.
- Data Requirement: To highlight key data requirements in prototype and implementation stages, which are not exhaustive and subject to further review. It is envisaged that the data to be consumed by the BEAP would come from a single source (i.e. the CSDI).
- Scale up of the Application: To consolidate the lessons learned during the prototype development, provide recommendations on future development of each prototype application as implementation project.

4.2.5.2 In general, the data requirements for setting up the platform can be grouped into the following categories and details of each type of data requirements to support the platform are summarized in **Appendix A**:

- Planning Context: Digital statutory planning information including OZP, layout plan, planning applications, etc.
- Cadastral and Topographical Context: Land administrative and geotechnical related information including private and government lots, leases conditions, slope, geological survey, etc.
- Environmental Context: Environment, greening and conservation related information including air, noise, air and water quality monitoring data, trees, agriculture, air ventilation, marine-related, etc.)
- Demographic Context: Population and demographic projection information including census, population projection and statistics, etc.
- Road and Transport Context: Road and transport related information including road network, pedestrian network, railway restriction boundary, etc.
- Utilities Context: Underground utilities information including the alignments of pipelines managed by various utility undertakers, water mains and drainage inventories, etc.

4.2.5.3 For details of each prototype applications including scope, functions and data requirements, please refer to "Final Technical Report on the Proof-of-Concept and Prototypes of the Test Case for BEAP".

4.3 Landuse Monitoring and Analytics

4.3.1 Background

4.3.1.1 With the advent of remote sensing technology, different kind of imagery has been widely used to help identify types of landuse and changes of landuse overtime. The current methodology adopted to prepare land utilization map by using remote sensing technology and GIS data is illustrated in **Figure 4.4** and **Figure 4.5**. Leveraging and integrating multi-source, -date and -level images collected from 'space', 'sky' and 'land', which are referred to satellite images, aerial photographs, images captured by UAVs, site photos and scanned images taken by moving vehicles, can help enhance the accuracy of the methodology to be adopted in undertaking landuse classification and detection of landuse change.

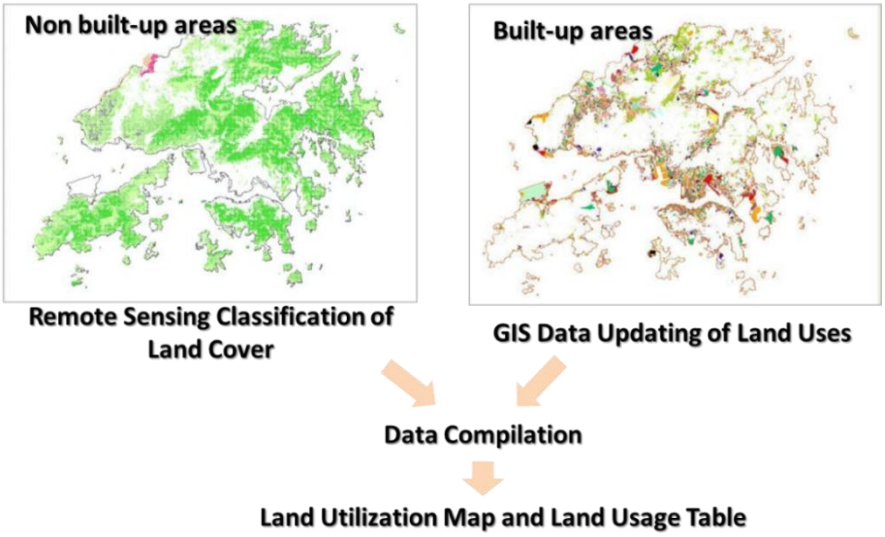


Figure 4.4 – Current Methodology of Identifying Land Utilization

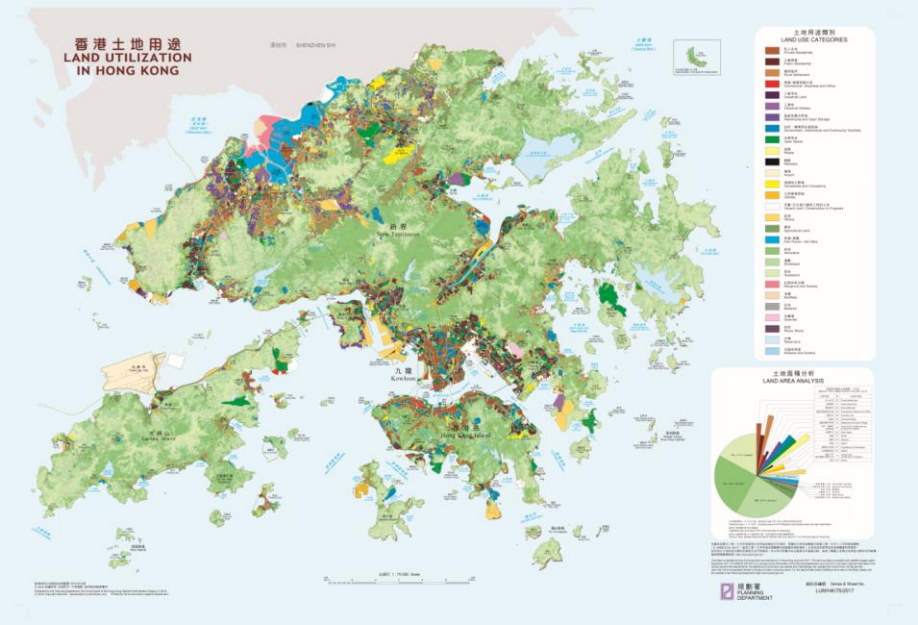


Figure 4.5 – Land Utilization Map

4.3.1.2 The Government has been facing challenges on how to effectively detect the landuse changes to prevent or discontinue the occurrence of illegal activities such as illegal waste dumping and land filling, unauthorized development, etc. The available multi-source, -date and -level images and related technologies can streamline and speed up conventional practice of labour-intensive field inspection and landuse mapping on regular basis.

4.3.2 Purpose

4.3.2.1 The key objectives of this application are to:

- Develop a single resource library platform which stockpiles multi- source, -date and -level data (e.g. satellite images, UAV/aerial photos, vehicle-based mobile images, survey data, videos, etc.) that are uploaded by different B/Ds and research institutes with clear tags and time descriptions;
- Visualize the change in LULC (e.g. green or water bodies to paved area or vice versa);
- Identify change on land surface height level based on DSM and DEM generated from LiDAR, UAV point cloud and aerial photos; and
- Facilitate the identification of specific landuses (e.g. brownfield sites)

4.3.3 Benefits

4.3.3.1 With the implementation of this application, it is envisaged that the following benefits can be realized:

- Users are able to easily search and navigate previous photos or videos uploaded through the resource library to have a clear picture on the development of different sites.
- LULC and their changes that are concerned by different B/Ds can be identified

and monitored in an automatic and systematic way. For example, land cover change detection can facilitate PlanD on monitoring unauthorised development such as illegal pond filing and land excavation. Surface height change detection can quickly identify unauthorised building works that are concerned by BD. It can also facilitate EPD to identify illegal dumpling and monitoring tree condition under tree preservation plan.

- Change detection results can be further integrated with other information and system in different B/Ds such as land lease and OZP, etc. to develop a landuse change monitoring and alert system to assist in identifying unauthorized developments/activities.
- Duplication of effort can be minimized since users are able to view the works done by other departments.

4.3.4 System Design

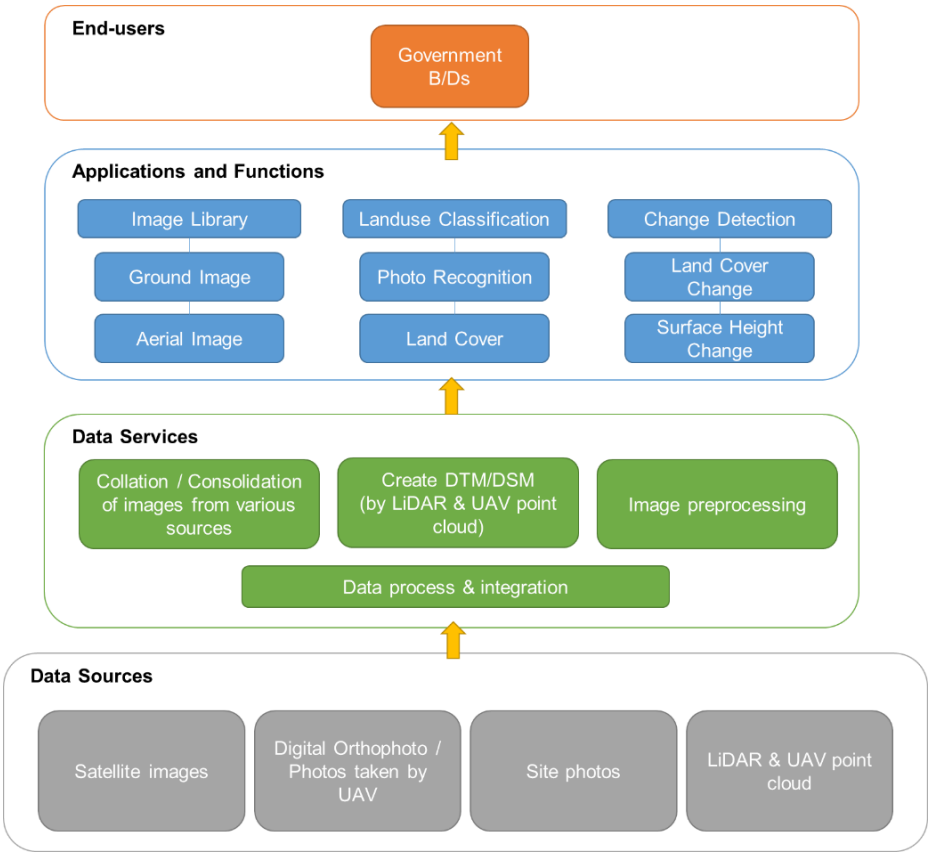


Figure 4.6 – Workflow Diagram of Landuse Monitoring and Analytics

4.3.4.1 Technical infrastructure:

i. Software: The application runs on web-based GIS, exchanging request with web-server and GIS server for data layer consumption. Backend data processing are carried out in GIS, image analysis software and open source machine learning library.

ii. Hardware: The prototype is developed and hosted in an on-premise environment. During the implementation stage, this application would likely

need to increase capacity for database, linkage with other built environment data and applications. The hardware requirement with setting of 8 core 2.6GHz CPU and 64GB RAM is recommended.

4.3.4.2 The Landuse Monitoring and Analytics application is undertaken by the following key steps as illustrated in **Figure 4.6** above:

i. **Image Library –** A collection of images from various sources including satellite images, digital orthophotos, photos taken by UAV, site photos (with content and location tagging), LiDAR data and UAV point cloud, etc. stored in a web-based interface for users to upload, browse and download.

ii. **Landuse Classification –** LULC classification utilising site photos, aerial photos and satellite images with deep learning image classification and recognition algorithms

iii. **Change Detection –** Change detection results for LULC and land surface height, which are produced based on satellite images, LiDAR data, aerial photo, UAV photos/point cloud collected from various years, could be visualized by using web interface. Subject to further investigation, web geo-processing tools can be incorporated in the application to undertake on-the-fly land cover and surface height change detection based on pre-processed land cover classification map and DSM/DEM.

4.3.5 Study Area

4.3.5.1 The land cover classification is processed for Yuen Long area using year 2016 WorldView-2 satellite image with brownfield polygon as ground truth data.

4.3.5.2 A land cover change detection is processed for Sik Kong Tsuen area in the west of Tin Shui Wai using year 2016 and 2017 WorldView-2 satellite images. Surface height change detection are processed for 2 different sites in Tin Shui Wai area for prototype demonstration.

4.3.5.3 Image library allows users to upload, browse and download on-site photo in ground photo image library. Brownfield site photos that are categorised into 10 usage types together with other non-brownfield photos are used in the prototype for demonstration. Users can also upload rectified aerial image for further processing and browse aerial image in map viewer. WorldView-2 satellite images, digital orthophotos, UAV and aerial photos from various years are used in prototype.

4.3.5.4 A deep learning photo recognition algorithm and a land cover classification algorithm are developed for brownfield type recognition for prototype demonstration. Photo recognition algorithm uses on-site brownfield photos categorised in 10 usage types as training data to develop a model for instant photo recognition of brownfield type.

4.3.6 Functions

The functions delivered and tested in the prototype development process and to be included or requiring further development in the implementation stage are summarised in **Table 4.1**.

	Key Functions		Prototype Development	Implementation Stage
i	Image Library	a. Upload, browse and download site photos, aerial images, satellite images, UAV point cloud, vehicle-based mobile image and video, and view description of uploaded images	- Partially delivered and tested - Upload, browse and download geo-tagged site photos and view photo description - Upload and browse aerial images - Browse satellite images	- Enhance photo library to allow creating new site photo category - Include upload, browse and download functions with UI for aerial images, satellite images, UAV point cloud, vehicle-based mobile images and videos - Allow inputting description of the uploaded images and manually add location point for site photos
		b. Send out auto-notification when new photos or videos of interested area are uploaded to applications	- Delivered and tested - Notifications included in the application of Built Environment Information Dashboard for site photo upload	- Email notification based on preference of interested area and image type
ii	Landuse Classification	a. Perform site photo recognition	- Delivered and tested - Incorporate the deep learning algorithm for site photo recognition - Allow uploading new photos in batch to run instant photo recognition for brownfield type - Save uploaded site photos into Photo Library by categories	- Add additional brownfield photos to enhance algorithm performance - Add photos of other landuse types for new photo recognition training - Develop a workflow to notify data scientist to re-run the algorithm if the number of newly

	Key Functions		Prototype Development	Implementation Stage
				uploaded photo reaches a certain quantity
		b. Visualize the results of satellite image recognition	- Delivered and tested - Incorporate the result of satellite image recognition using deep learning algorithm (identification of brownfield type for Yuen Long area)	- Include brownfield classification for whole Hong Kong - Identify other LULC types for landuse classification - Apart from site photo and satellite image recognition, incorporate aerial photos from LandsD for landuse classification
iii	Change detection	a. Visualize the results of land cover change detection	- Delivered and tested - Incorporate the results of land cover classification map for Tin Shui Wai area in 2016 and 2017 - Provide a web interface to visualize the land cover classification map of Tin Shui Wai area in 2016 and 2017 and the change detection results and corresponding satellite image	- LULC classification for the entire Hong Kong - More LULC types can be classified - Allow uploading pre-processed land cover classification map and carried out instant land cover change detection - Send alert for changes in specified area (also applicable to function (iii)(b))

	Key Functions		Prototype Development	Implementation Stage
		b. Perform surface height change detection	- Partially delivered and tested - Incorporate the results of surface height change detection in two areas i.e. near Tin Shui Wai and near Fuk Shun Street - Provide a web interface to visualize surface height change detection results of pre-processed DSM and the corresponding aerial/UAV photos	- Incorporate the algorithm of surface height change detection into the application - Utilize pre-processed DSM and carry out instant surface height change detection

Table 4.1 – Functions of Application in Prototype and Implementation Stages

4.3.7 Data Requirement

4.3.7.1 Interfacing datasets used in this prototype, as well as suggested additional datasets subject to further review for implementation are listed in **Table 4.2**. During the future implementation stage, further liaison and agreement with respective B/Ds on the use of the datasets in the application would be required.

B/Ds / Other Parties	Data / Dataset for this Application	Included in Prototype Stage	Included in Implementation Stage
LandsD	Digital Topographic Map iB1000, iB5000, iB10000, iB20000	Yes	Yes
	Digital Orthophoto DOP5000	Yes	Yes
CEDD	LiDAR Data (2011)	Yes	Yes
PlanD	Brownfield Sites Polygon	Yes	Yes
	Brownfield On-site Photo	Yes	Yes
	WorldView-2 Satellite Image (2016 & 2017)	Yes	Yes
	Digital Orthophoto & DSM (1993, 2017, 2018, 2019)	Yes	Yes
	Land Utilization Map	No	Yes
HyD (Survey Division)	Vehicle-based mobile image	No	Yes
PolyU	Landuse classification map	Yes	Yes

Table 4.2 – Data Requirement of this Application

4.3.8 Scale up of the Application

4.3.8.1 Algorithm for photo recognition using vehicle-based mobile images can be developed to identify various usage types such as retails shop, commercial and residential, etc. to facilitate urban landuse classification.

4.3.8.2 Algorithm to integrate topographic map from LandsD, photo recognition results of geo-tag site photos and land cover classification into a single system to support the preparation of land utilization map.

4.3.8.3 A territory wide landuse monitoring system for B/Ds can be developed to monitor various landuse changes such as unauthorized building works verified by BD, illegal dumping monitored by EPD, etc. Additional information from B/Ds (e.g. terms and conditions in land lease, or development control parameters stipulated in OZP) can be further integrated with change detection results to automatically identify the area that violates the land/development control conditions. This monitoring system can be further enhanced to send notification to concerned B/Ds according to types of landuse changes and geographic locations.

4.4 Site Search

4.4.1 Background

4.4.1.1 During planning and design stage of developments, relevant B/Ds would need to undergo an initial screening of potential sites based on various searching criteria to identify suitable sites for different purposes.

4.4.1.2 The current Site Search System under PlanD (**Figure 4.7**) is tasked to identify suitable areas for development of particular uses to meet the requirements of concerned B/Ds or for other operational needs. It provides multiple selection criteria, such as site area, district, land status, zoning, environmental factor, etc. to identify sites with different requirements. A notification via email would be sent to the staff, which would provide a hyperlink to access the searching results.

4.4.1.3 To initiate the site search, the project proponent (B/Ds user) is required to provide site requirements and fill in required information set out in the site search form (e.g. locational preference, policy support, justifications, programme, operational details, etc.) according to DEVB General Circular No. 1/2016. Based on the request of the project proponent and site requirements, PlanD undertakes to conduct site search for permanent use with a set of criteria and would initiate internal consultation with different offices / sections of PlanD to examine whether any available sites are suitable to meet the site search requirements.

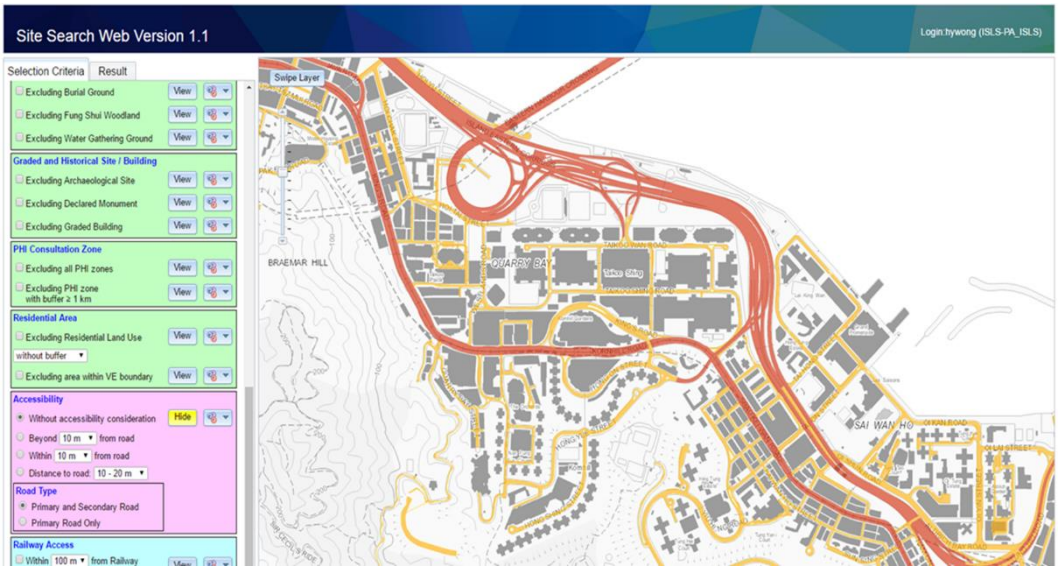


Figure 4.7 – Existing Site Search System in PlanD

4.4.1.4 Under current practice, B/Ds would submit their site search form via an email and there is no web-based platform with workflow management to handle the requests from B/Ds or allow easy visualization of the searching results. Also, under the existing system, a relatively long processing time is required to generate the results depending on the search criteria, and in some cases the accuracy of the results may not meet the requirement due to obsolete or inadequate layers of searching criteria and possible data loss rising from adoption of the conventional raster-based approach in searching process. The current system also lacks prioritisation of filtering functions to generate more accurate results.

4.4.2 Purpose

4.4.2.1 This prototype is to develop a new version of site search tool on the basis of the current Site Search System with the following objectives:

- Develop a collaborative platform for B/Ds to circulate site search requests for processing by PlanD;
- Perform suitability analysis by generating information on the relative suitability of different locations for accommodating future landuse demand, factoring in various selection criteria;
- Visualize search results through a GIS platform, designed with a user-friendly interface;
- Provide a site search database to retrieve search records for comparison with previous search requests;
- Update site search criteria and layers and improve accuracy of results generated by the current system; and
- Improve the user-experience with the prioritisation of results by providing the weighting of different search criteria according to users' preferences

4.4.3 Benefits

4.4.3.1 With the implementation of this application, it is envisaged that the following benefits can be realized:

- Provide a one-stop platform for B/Ds to make site search requests with their preferences on various searching criteria such as preferred locations, site area, accessibility, surrounding environment, etc. to enhance the efficiency in circulating site search requests. PlanD can then base on these requirements to conduct site search and make recommendations in an effective manner;
- Facilitate B/Ds users to consider and discern the site search results from PlanD by overlaying site search results onto various base maps and generating reports showing the selection criteria, site location map, and relevant site details including comments from departments;
- Ensure single source of data when a coordinated platform for site search is provided among B/Ds;
- Efficiency of decision-making process in choosing sites can be boosted as the processing of site search requests would be expedited with more accurate results;
- Enable decision makers to have an overall picture of all possible available options and allow comparison of important features between different potential sites.

4.4.4 System Design

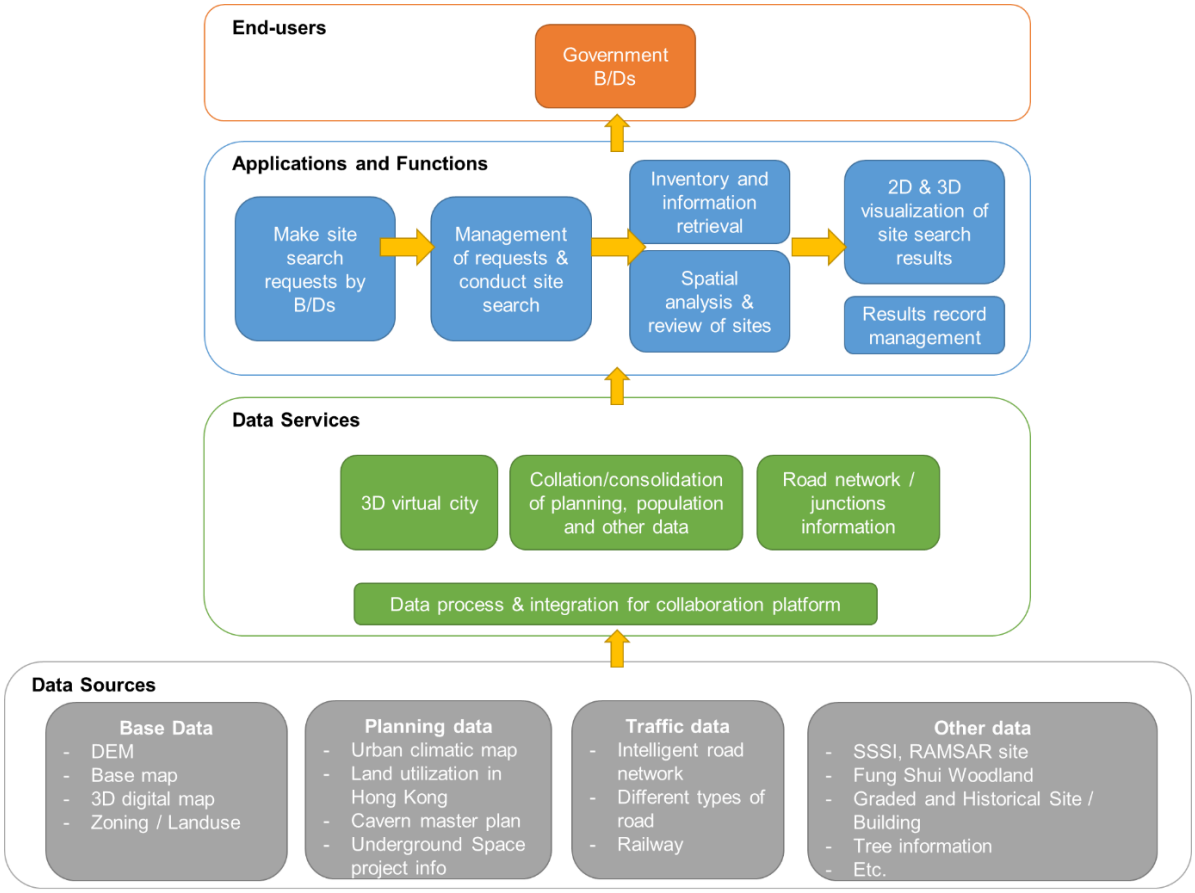


Figure 4.8 – Workflow Diagram of Site Search Application

4.4.4.1 The application will include tools for performing spatial analysis on existing geospatial datasets of land to generate a selection of sites matching the search criteria as submitted by project proponent. Users will be able to visualize the locations of the site, alongside detailed information on the size, zoning, OZP plan numbers (if any), location, existing use, site availability, etc. regarding the selected site results. Users can also generate a record of site search results as a document, or as spatial data file, for further analysis.

4.4.4.2 Technical infrastructure:

i. Software: The application aims to enrich the existing GIS-based Site Search System maintained by PlanD, which visualizes and updates essential information on the interactive map interface that runs on a web-based GIS platform exchanging requests with web-server and database for spatial analysis. Maps are created on open source framework using D3.js JavaScript Library and Cloudflare security.

ii. Hardware: In the implementation stage, processing time for generation and display of search results can possibly be shortened by use of multiple virtual machines each equipped with higher number of cores (e.g. 16-core 2.6GHz CPU) and more RAM (e.g. 64GB).

4.4.4.3 The application is undertaken by the following key steps (**Figure 4.9**):

i. The overall application development requires an understanding of available data sources and performance of existing Site Search System to identify functional requirements for further enhancement / development. DEM, 2D / 3D digital maps, and base maps are the fundamental elements for visualization while zoning maps, landuse, planning, accessibility, environmental and other relevant data form the database for spatial analysis. The workflow is shown in **Figure 4.8** above.

ii. When B/Ds users submit the request for site search, they are required to input all details of site requirements such as location, considerations regarding accessibility, transportation, environmental and ecological impacts to the web-based interface, which is transformed from the original paper-based site search form. Users can upload all supporting documents when submitting the request. Notification of requests will be sent out to B/Ds users and PlanD users (New Territories District Planning Division Headquarters (NTHQ) and District Planning Offices (DPOs)), which will then be displayed as an individual "Job" with unique ID no. to be processed. When a job item is created, it would be directed to relevant responsible section / office of PlanD for processing and deadlines for completion of searching exercise will also be set for better workflow monitoring. Users can view the job status through the platform and will be kept informed of the updates in job status.

iii. Upon receipt of all relevant information, preliminary site search exercise based on requirements can be conducted. The information stored in the platform will be retrieved to check against the selected criteria and spatial analysis will be carried out to identify suitable site(s) fitting the profiles. Results can be further prioritised based on user preferences (e.g. noise level, building age, proximity to hospitals and schools). Site agglomeration within a certain buffer zone will be conducted to combine sites of similar characteristics with smaller size as an individual plot to match the size required. After potential site(s) is/are identified, PlanD will examine the search results and recommend the suitability of the sites and inform B/Ds users of the final searching results with comments, if any, via the platform.

iv. B/Ds users can view the results via the platform, including site location and relevant information in spatial dimension via 2D / 3D environment. The results can also be exported in tables or reports and the corresponding site polygons in shapefile formats can be downloaded as well. Upon receipt of the search results, B/Ds users can also refine the site requirements and initiate new site search requests via the platform, if required.

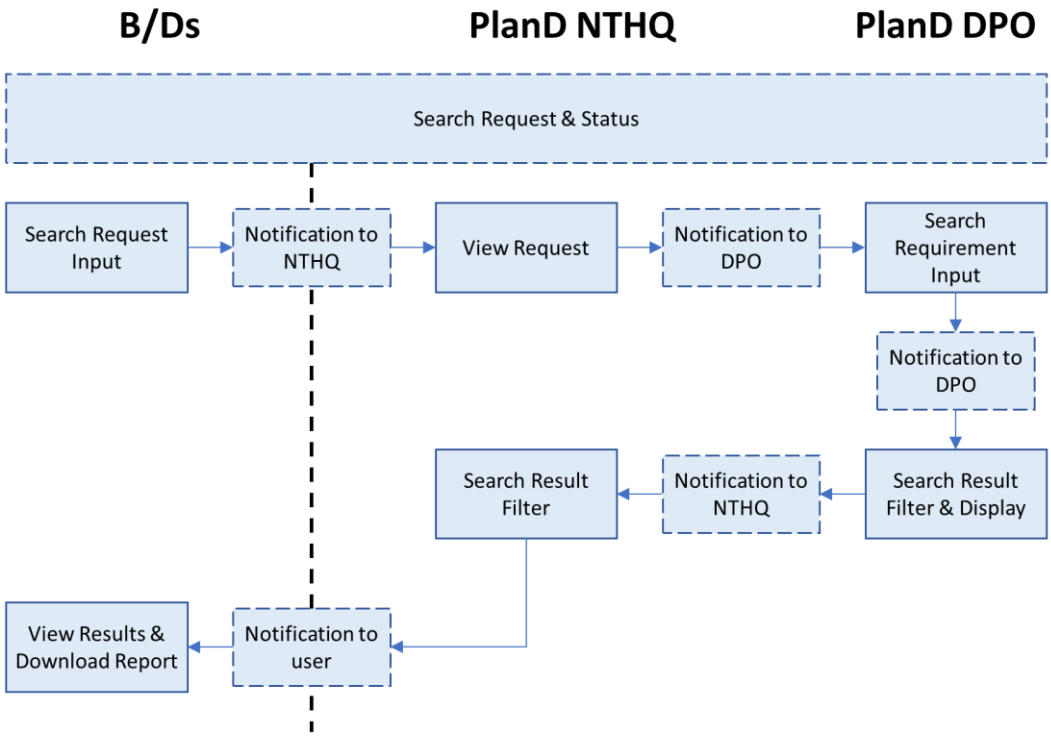


Figure 4.9 – Flow and Operation of Site Search Application

4.4.4.4 The application has the following two key user classes:

- B/Ds users: project proponent requesting for suitable sites to meet their requirements; and
- PlanD users: processing agent (e.g. NTHQ and DPOs) to handle and process the site search requests

4.4.4.5 The access right to the details of the searching job and the functions of the application would be determined by different user classes. Details are shown in **Table 4.3**:

B/Ds Users	PlanD Users	
	NTHQ	DPOs
• View the job status (e.g. request received, processing or completed, etc.) after submission of the site search requests • Upon completion of the site searching exercises by PlanD, view and download the results	• View the job status and details of the request • Scrutinise all requests submitted by B/D users • Assign relevant DPOs to process the site search requests • Set deadlines for completing the site search • Screen and add further comments to the searching results generated by DPOs	• View the job status and details of the requests assigned by NTHQ • Process the jobs assigned by NTHQ using the functions of the application • Identify the suitable sites and make comments to the results

Table 4.3- User Class Accessibility

4.4.4.6 All users will receive notifications regarding any change of job status (e.g. Request Received, Processing and Completed, etc.).

4.4.5 Study Area

4.4.5.1 The prototype is developed at territorial scale. The data layers in relation to site, environment, conservation and accessibility have been included in the prototype to serve as searching criteria, excluding underground-related data.

4.4.6 Functions

4.4.6.1 The functions delivered and tested in the prototype development process and to be included or requiring further development in the implementation stages are summarised in **Table 4.4**.

	Key Functions		Prototype Stage	Implementation Stage
i.	Site search work flow management	a. Allow submission of site search requests via web-based input interface	- Delivered and tested - The paper-based site search form is converted into web-based input interface	- Further refinement of the input interface with inclusion of other searching requirements (e.g. cavern sites, underground space, etc.)
		b. Input and modify the search parameters	- Delivered and tested	- To be included
		c. Allow users to upload other documents/ information to support the site search requests	- Delivered and tested - Allow only single uploading of documents/ information to support site search requirements by user (e.g. details of requirements, constraints, policy support from relevant bureaus, etc.)	- Allow multiple uploading of the relevant information and documents to support different site search requirements
		d. Allow withdrawal of site search	- Delivered and tested	- Allow modification of the details of the site search requests after submission

	Key Functions		Prototype Stage	Implementation Stage
		requests after submission	- Able to withdraw the requests after submission	
		e. Send notifications to relevant users regarding change in job status	- Delivered and tested	- To be included
		f. Assign site search job to relevant users for further processing	- Delivered and tested - NTHQ users can set deadline for site search jobs and assigning the jobs to the corresponding DPOs for processing	- To be included
		g. View the details of the site search requests and job status	- Delivered and tested	- To be included
		h. Allow different access right based on different user classes	- Delivered and tested	- To be included
ii.	Perform suitability analysis with automatic generation of searching results	a. Auto-fill the site search parameters based on the input by the users via the web-based interface (e.g. site area)	- Delivered and tested - Allow auto-filling some direct and simple parameters e.g. numeric input	- Allow auto-filling more inputs by users into the search parameters to minimize the manual input efforts
		b. Allow the input of search criteria and modification	- Delivered and tested	- To be included

	Key Functions		Prototype Stage	Implementation Stage
		to the search parameters		
		c. Enable site agglomeration in the searching process	- Delivered and tested	- To be included
		d. Allow filtering of search results with auto-generation of corresponding lot numbers for sites identified in the search results	- Delivered and tested. - Allow removing some identified sites from the search results	- Allow removing identified sites and adding new sites from other sources in the search results. - Enhance the accuracy of the auto generation of lot numbers and even of the full address for the sites identified.
		e. Archive the site search requests and associated results for retrieval	- Delivered and tested.	- To be included
iii.	Interactive map visualization through GIS platform	a. Check site search results on the map interface with pan and zoom functions	- Delivered and tested	- To be included
		b. Overlay the site search results with different thematic layers and basemaps, supplemented with other information e.g. basic places / road names	- Delivered and tested - Overlay the site search results onto 3D environment with different display features e.g. on / off the layers and adjustment to transparency - Display the corresponding names of places	- Through API services to update the required basemaps on a regular basis - Allow integration of the site search results with 3D mesh model for better visualization - Allow locational search with wide range of keywords

	Key Functions		Prototype Stage	Implementation Stage
			(e.g. buildings / GIC facilities) and roads interactively on 2D base maps depending on zoom intensity.	- Enable display of place/street/road names on 3D model
iv.	Display, export and review search results	a. Generate tables of site search results and allow the download of reports and identified site polygons in shapefile formats	- Delivered and tested	- Allow generation of output showing either single site or multiple selected sites within one report - Allow downloading shapefiles of single site and multiple sites
		b. Enable comparison and sorting of results and input annotations and provide comments onto search results	- Delivered and tested - Allow sorting results within table by predefined criteria e.g. size of the site, job ID, proximity to facilities, noise level, etc.	- Allow comparison of results and highlighting differences in parameters between selected search results - Allow provision of drop-down menu with default input of additional site information based on relevant database (e.g. site availability or current site users) to facilitate filtering the search results or tendering comments on the sites identified

Table 4.4 – Functions of Application in Prototype and Implementation Stages

4.4.7 Data Requirement

4.4.7.1 Interfacing datasets used in this prototype, as well as suggested additional datasets subject to further review for implementation are listed in **Table 4.5**. During the future implementation stage, further liaison and agreement with respective B/Ds on the use of the datasets in the application would be required.

B/Ds / Other Parties	Data / Dataset for this Application	Included in Prototype Stage	Included in Implementation Stage
LandsD	Digital Topographic Map iB1000, iB5000, iB10000, iB20000	Yes	Yes
	Digital Land Boundary iC1000	Yes	Yes
	GeoReference Data iG1000	Yes	Yes
	Digital Orthophoto DOP5000	Yes	Yes
	GeoCommunity Database (i.e. schools, community facilities, etc.)	Yes	Yes
	3D Spatial Data (i.e. Buildings, Roads, Terrain, etc.)	Yes	Yes
	Village Environment Boundary	Yes	Yes
	Railway Station	Yes	Yes
	Waterfront	Yes	Yes
	Closed Area Boundary	Yes	Yes
	DTM	Yes	Yes
	Pedestrian Network	No	Yes
CEDD	LiDAR Data (2011)	Yes	Yes
	Man-made Slope	No	Yes
	Cavern Sites	No	Yes
PlanD	DPO Boundary	Yes	Yes
	Age of buildings	Yes	Yes
	OZP Zoning	Yes	Yes
	3D Photorealistic Mesh Model	Yes	Yes
	SSSI	Yes	Yes
	PHI Zones	Yes	Yes
	Facilities for the Elderly	Yes	Yes
	Other GIC facilities	Yes	Yes
	School	Yes	Yes
	Statutory Planning Scheme Boundary	Yes	Yes
	Land Utilization Map (Vegetation Cover)	Yes	Yes
AFCD	Country Park	Yes	Yes
	GeoPark	Yes	Yes
	Ramsar Site	Yes	Yes
	Special Area	Yes	Yes
	Fung Shui Woodland	Yes	Yes
WSD	Water Gathering Ground	Yes	Yes
AMO	Archaeological Site	Yes	Yes
	Declared Monument	Yes	Yes
	Graded Building	Yes	Yes
TD	Intelligent Road Network	Yes	Yes
MTR	Railway Protection Zone	Yes	Yes

Table 4.5 – Data Requirement of this Application

4.4.8 Scale up of the Application

4.4.8.1 Through interfacing with GIC Facilities and Open Space Analysis prototype, analytical functions such as service area analysis can be incorporated to develop a more comprehensive view of the opportunities provided by potential sites. It will also provide an additional depth to analysis, where site search can consider co-location of facilities, whether there is a duplication of facility, or the adequacy of existing facility to provide extra information for PlanD users.

4.4.8.2 An upgrade for technical hardware for result generation and display in future implementation will reduce processing time and increase efficiency in site search process.

4.5 Scenario Generation for Planning and Development

4.5.1 Background

4.5.1.1 Long-term land development of Hong Kong must be carefully planned to meet housing, economics and other landuse needs of the territory. To ensure sustainable land development, a planning and engineering study of each new site development must be carefully carried out to formulate recommended Outline Development Plan, perform technical assessment and formulate implementation programme.

4.5.1.2 The current planning process of developing a landuse scheme is made of several iterative loops, involving B/Ds as well as the general public, for option formulations and technical assessments. Throughout the process, the baseline situation will be analysed first; and then various technical impact assessments will be conducted to explore the technical feasibility of this landuse scheme.

4.5.1.3 To produce a landuse scheme with different building masses for the subsequent technical assessments is already a complex process, which different parameters, design criteria, statutory requirements, local context and conditions, etc. need to be taken into account. Some typical examples are listed as follows:

- Development targets and objectives (e.g. resident population, working population, etc.);
- Location of various public and community facilities, district open space, etc. as required under HKPSG;
- Site classification, development intensity, plot ratio and site coverage at different lots;
- Accessibility including current transport network and emergency access arrangement; and
- Building separation, height limitation, setback, orientation, site greenery and ventilation requirements as required in the Sustainability Building Guidelines and other planning and building requirements.

4.5.1.4 The variations and different criteria of producing a landuse scheme leads to long study time where only a limited number of options can be investigated, since the impact of updating the development cannot be instantaneously assessed and visualized.

4.5.1.5 Therefore, using a parametric model, with related development goals, rule-based regulatory constraints and related design and planning criteria digitalized, B/Ds could have an application to generate various landuse schemes in a flexible way for comparisons and discussion with relevant parties under a digital environment. As such, the process of option formulation would be accelerated and option analysis would be facilitated. This would enable a larger number of options formulation to be reviewed in a shorter study timeframe, formulating better options for new area developments.

4.5.2 Purpose

4.5.2.1 At present, design parameters, relevant regulations and guidelines have yet to be digitalized in a single platform. There is also a lack of a platform providing 3D

view of proposed development together with the surrounding area, and lack of algorithms to support visualization of results after modifying various design parameters.

4.5.2.2 This prototype is to develop a scenario generation tool that allows B/Ds and consultants to share information, analyse, modify and generate a preliminary landuse scheme (with building masses) for NDAs, or a particular area/site for subsequent technical assessments. The key objectives are to:

- Provide a digital twin 3D model to visualize the planning project parameters and surrounding environment
- Provide a tool for users to input design parameters e.g. plot ratio, site coverage, maximum building height, number of blocks, etc. to visualize the building masses in 3D view
- Carry out options formulation following related planning and building guidelines and regulations
- Modify design parameters and visualize instant results
- Facilitate comparison between proposed options
- Put annotations and comments on scenarios to facilitate convergence of opinions

4.5.3 Benefits

4.5.3.1 With the implementation of this application, it is envisaged that the following benefits can be realized:

- Initial option generation process within B/Ds can be facilitated by inputting preliminary development parameters of different land parcels and road network.
- Review process between B/Ds can be conducted in systematic and efficient manner with regards to different landuse schemes, and therefore the whole process in the planning stage of developing new development area or a particular site and enhance communications can be expedited.
- Easy comparison of key development parameters (such as population, housing supply, employment opportunities, commercial/industrial floor area, etc.) between options.
- Consultation and feedbacks from B/Ds and experts are facilitated in the 3D environment to clearly assess and visualize proposal leading to accelerated convergence for future development projects.

4.5.4 System Design of the Application

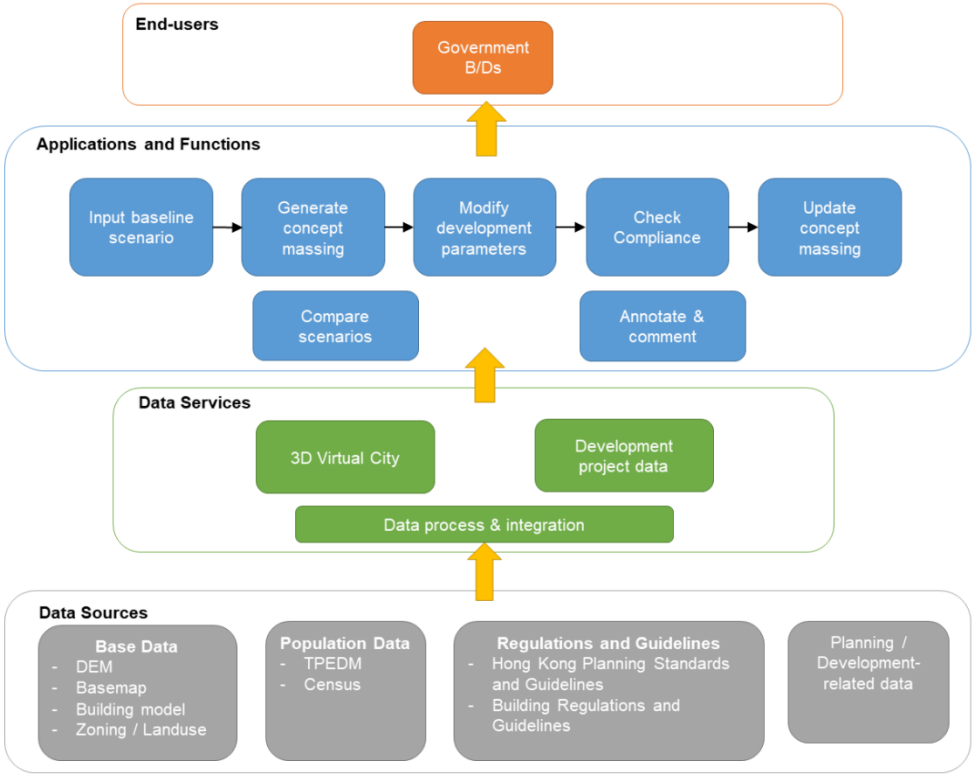


Figure 4.10 – Flow Diagram of the Application

4.5.4.1 Technical infrastructure:

i. Software: The prototype is developed based on a proprietary software which provides web interface for the required functions. During the implementation stage, it is recommended to assess whether the proprietary or open source software is the most suitable technology for the application development.

ii. Hardware: The prototype is developed on private cloud environment which is appropriate for short term showcase development. During the implementation stage, the hardware requirement with the setting of 16 core 2.6GHz CPU (or above) and 64GB RAM (or above) to support the heavy computational functions of the application is recommended.

4.5.4.2 As illustrated in **Figure 4.10**, the application will include tools to perform option formulation and review in the context of the landuse scheme proposal of a new development area. The users will be able to visualize existing development, to modify them to carry out option formulations and to visualize instant results. Once one or several options are formulated, the users will be able to annotate the outcome in order to communicate with other B/Ds.

4.5.4.3 The application will include the following functions:

i. Visualize baseline parameters of previous and current planning projects and surrounding environment

ii. Define and modify transport network, landuse type and corresponding planning parameters

iii. Visualize instant results of changes in district KPI resulting in modification of scenario

iv. Check violation of those planning parameters against baseline planning requirements, and provide reminders of noncompliance

v. Check compliance of related planning and building guidelines/regulations of each formulated planning option, and provide reminders of noncompliance

vi. Provide comments to the options

vii. Interface with other applications and software

4.5.5 Study Area

4.5.5.1 The prototype is built retrospectively by using Hung Shui Kiu (HSK) area in **Figure 4.11** as an example of New Development Area (NDA)[34] where basic planning layouts have been formulated.

Figure 4.11 – Hung Shui Kiu Area

4.5.6 Functions

4.5.6.1 In order to implement this application, the key users group needs to include representatives of B/Ds that define regulations and guidelines in order to ensure appropriate implementation of the Hong Kong guidelines. This will enable:

- Understanding of various end-user requirements

[34] https://www.hsknda.gov.hk/ (HSK NDA Study was completed which data was used in this prototype application)

- Prioritization of guideline digitalisation and checking according to key government needs of simulation and compliance control
- Facilitation of change management and adoption for all users
- Accurate definition of required data and data sources

4.5.6.2 The functions delivered and tested in the prototype development process and to be included or requiring further development in the implementation stage are summarised in **Table 4.6**.

	Key Functions		**Prototype Development**	**Implementation Stage**
i	Visualize baseline parameters of previous and current planning projects and surrounding environment in 3D environment	a. Allow inserting information on land parcel distribution and development parameters via shapefiles and tables	- Delivered and tested	- Include information of other NDAs and planning projects subject to data availability
		b. Visualize building masses and transport network	- Delivered and tested - Show the building masses according to the height and built form - Show street centre lines - Show land parcels in different colours according to the landuse types	- Include 3D model of transport infrastructure
		c. Conduct simple 3D dimensional measurements	- Delivered and tested - Length, altitude and area can be measured	- Include 3D volume measurement
		d. Click individual land parcel/building and show their corresponding development parameters	- Delivered and tested - View landuse type and development parameters	- Show more details of landuse such as types of GIC facilities
ii	Define and modify transport	a. Modify landuse types and development	- Partially delivered and tested	- Allow modification of land parcel's shape

	Key Functions		Prototype Development	Implementation Stage
	network, landuse type and corresponding planning parameters	parameters for selected land parcel(s) (**district level**)	- Modify limited planning parameters	- Allow changes of more development parameters
		b. Modify landuse types and development parameters of an individual land parcel (**site level**)	- Partially delivered and tested - Modify limited planning parameters	- Allow changes of more development parameters and to individual building level - Include more built forms of building blocks
		c. Provide automatic generation of landuses based on user-defined parameters (e.g. radius of influence, weighting, etc.)	- Delivered and tested	- Include more landuse types (e.g. industrial land, open space, etc) and allow mixed use
		d. Create new and modify transport network based on pre-defined standard road types	- Delivered and tested - Include expressway, district distributor, and local distributor	- Include all standard road types
iii	Visualize instant results of changes in district KPI resulting in modification of scenario	a. Show an updated set of planning parameters in KPI dashboard after each modification	- Delivered and tested	- To be included
iv	Compliance checking of planning and building guidelines/ regulations	a. Incorporate suitable planning and building guidelines/regulations for compliance checking and show alert for non-compliance	- Partially delivered and tested - Include checking of building height and building separation	- Further liaise with B/Ds to identify more related planning and building guidelines/regulations to be incorporated for compliance checking

	Key Functions		Prototype Development	Implementation Stage
v	Provide comments to the scenario	a. Develop an interface for comments	- Delivered and tested - Comment through web interface	- Export the scenario in table or chart format for comments

Table 4.6 – Functions of Application in Prototype and Implementation Stages

4.5.7 Data Requirement

4.5.7.1 Interfacing datasets used in this prototype, as well as suggested additional datasets subject to further review for implementation are listed in **Table 4.7**. During the future implementation stage, further liaison and agreement with respective B/Ds on the use of the datasets in the application would be required.

B/Ds / Other Parties	Data / Dataset for this Application	Included in Prototype Stage	Included in Implementation Stage
LandsD	Digital Topographic Map iB1000, iB5000, iB10000, iB20000	Yes	Yes
	Digital Orthophoto DOP5000	Yes	Yes
	3D Spatial Data (i.e. Buildings, Roads, Terrain, etc.)	Yes	Yes
CEDD	LiDAR Data (2011)	Yes	Yes
	Rockhead layer	No	Yes
PlanD	HKPSG	Yes	Yes
	OZP	Yes	Yes
	3D Photorealistic Mesh Model	Yes	Yes
	HSK NDA Project Information	Yes	Yes
	Information of other NDAs and planning projects	No	Yes
TD	Intelligent Road Network	Yes	Yes
BD	Building Regulations and Guidelines	Yes	Yes
HD	Public Rental Housing Standard Block Layout	Yes	Yes
UUs	Underground utility networks	No	Yes
Other stakeholders or relevant B/Ds	Building foundation piles	No	Yes

Table 4.7 – Data Requirement of this Application

4.5.8 Scale up of the Application

4.5.8.1 In the future, output information of this application shall facilitate conducting preliminary traffic and environmental impact assessment such as traffic flow, air and noise pollution, thermal comfort and pedestrian walkability, to provide a quick overview for design consideration.

4.5.8.2 Other planning considerations such as SBD that specifies building setback from road to improve air ventilation and minimum coverage percentage of greenery areas should be included.

4.5.8.3 Economic, environment and social information such as development cost estimation and walkability, etc. could be incorporated in the application for a more comprehensive planning.

4.5.8.4 In the long run, the platform can integrate planning conditions and criteria with a library of typical Hong Kong building blocks and landscape for urban greening to facilitate master planning using parametric design with preliminary impact assessments.

4.6 GIC Facilities and Open Space Analysis

4.6.1 Background

4.6.1.1 The provision of GIC facilities in Hong Kong is based on the key factors such as population density and growth, and various socio-economic requirements. The HKPSG serves as a general guideline for assessing the provision of GIC facilities and open space, with general guidance and principles for measuring the adequacy of facilities to serve the needs of local residents or the wider district, region or territory. For example, the HKPSG has provided the provision requirements regarding number of school places per 1,000 persons, the minimum site area for a school and the level of accessibility.

4.6.1.2 Over the past 20 years, C&SD updates population projections for the whole territory every 2 to 3 years with a projection period of 50 years. In addition, projections of geographical distribution of population by DC District, New Town and TPU are prepared by the WGPD of PlanD to provide a basis for forward planning at local levels. PlanD also updates another set of TPEDM population projection data regularly, serving a primary purpose for strategic transport modelling, with different assumptions regarding future territorial population, economic growth and employment structure, etc.

4.6.1.3 Open spaces developed by either the public or private sector offers space for passive and active recreation, often providing recreational facilities of local or district significances. These may include parks, gardens, playground, promenade, pavilions, sitting out area, pedestrian area, etc. Public open space is mainly located on government land, while private developments may provide some publicly accessible facilities or public open spaces which can be governed by conditions of land leases. Examples of public open space managed by the government may include public parks and gardens, managed by LCSD, and open space within public housing development, managed by HD.

4.6.1.4 There is a lack of common platform for B/Ds to easily access to the inventory of the existing and planned facilities and open spaces in 2D/3D environment. Visualization of geographical distribution of GIC facilities / open space is limited by type and no spatial analysis is currently available to assess the coverage or extent of services to be provided by different GIC facilities and open space within a district.

4.6.2 Purpose

4.6.2.1 The key objectives of this application are to:

- Generate GIC table showing the provision of the existing and planned GIC facilities and open space based on the population projection and in accordance with the requirements of HKPSG;
- Visualize the distribution of the existing GIC facilities and open spaces to carry out service coverage and travel time analysis; and
- Conduct service area analysis for different GIC facilities and open spaces.

4.6.3 Benefits

4.6.3.1 With the implementation of this application, it is envisaged that the following benefits can be realized:

- A common application with easy visualization of the supply and demand of GIC facilities and open space, serving as a high-level GIC and open space monitoring platform and future planning tool for the provision of new GIC facilities and open space;
- Provision of quick analysis to identify the needs for new GIC facilities and open space for further exploration; and
- Assess the extent of coverage for different GIC facilities and open spaces to facilitate decision-making during planning for new GIC facilities and open space.
- B/D users can visualize the spatial distribution of GIC facilities and open spaces and facilitate the future planning for relevant GIC facilities and open space.

4.6.4 System Design

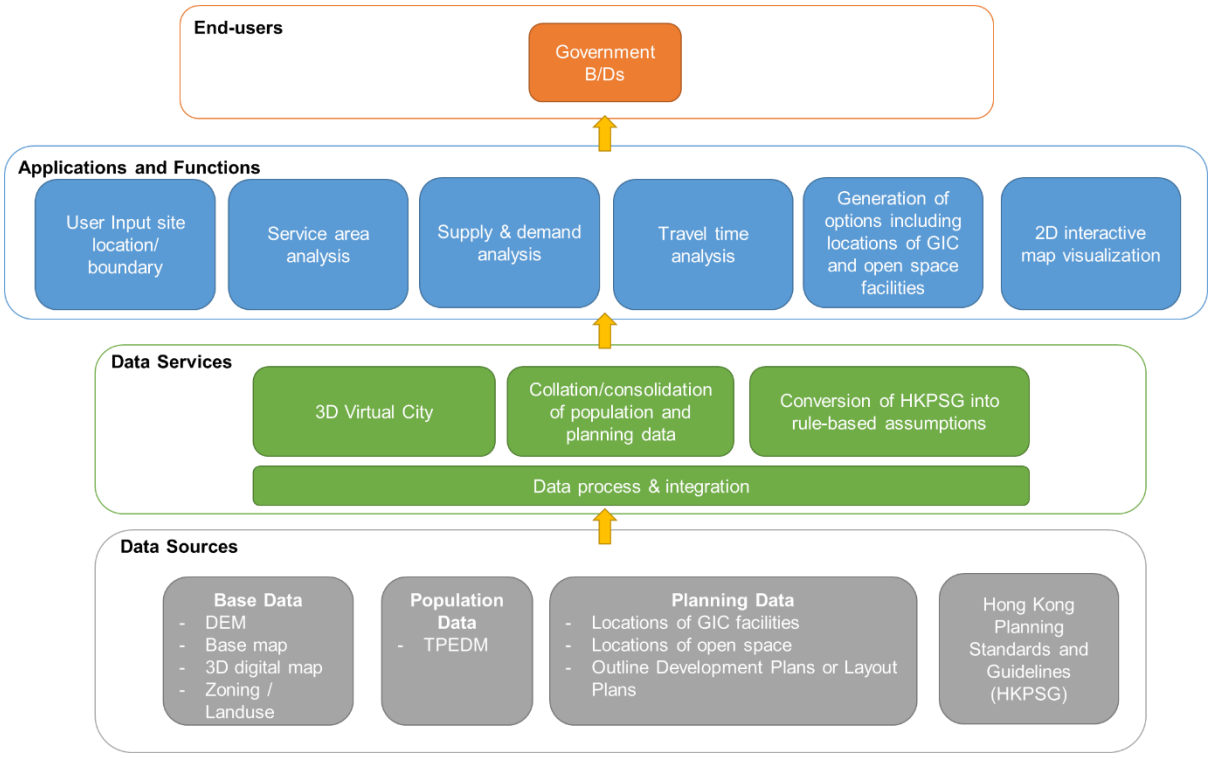


Figure 4.12 – Workflow Diagram of Application

4.6.4.1 The application will be developed with a GIS-based platform incorporating essential planning data, such as locations of GIC facilities and open space, the OZP and districts boundaries and population data. These data will be consolidated to become a fundamental back-end database. Provision requirements for different GIC facilities and open space stated in HKPSG will be converted into rule-based assumptions for provision analysis.

4.6.4.2 Technical infrastructure:

i. Software: The application runs on web-based GIS, exchanging request with web-server and database for spatial analysis. Maps are created on open source framework using D3.js JavaScript library and Cloudflare security.

ii. Hardware: Hybrid on-premise and cloud-based storage and Cesium web mapping service are adopted for online hosting GIS application to perform different functions. Implementation of the application would require 8 core 2.6GHz CPU (or above) and 64GB RAM (or above) for smooth operation of functions. Future scale up of the application would need to increase capacity for database, linkage with other built environment data and applications.

4.6.4.3 The application is undertaken by the following key steps:

i. The prototype development first incorporates the standards of different GIC facilities and open space provision as stated in the HKPSG for requirement on provision. Workflows are as shown in **Figure 4.12** above.

ii. Users from PlanD can choose the concerned area (either DC or OZP boundaries) and input existing and planned population to generate GIC tables for different districts from this application.

iii. Users in other B/Ds can visualize the spatial distribution of GIC facilities and open space. Simple information regarding the GIC facilities and open spaces (e.g. size, location) will be provided from web-based map.

iv. Service area analysis for different GIC and open space facilities are calculated based on travelling distances of different age groups. The population covered / uncovered by GIC and open space facilities will also be provided.

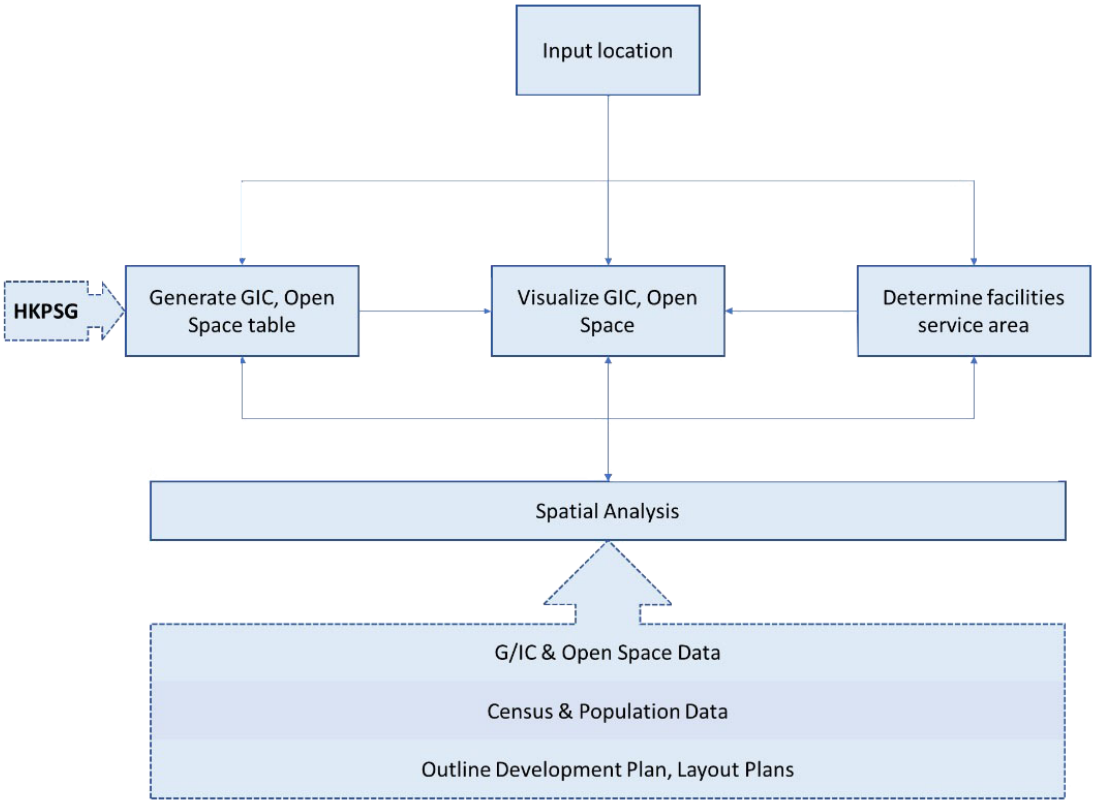


Figure 4.13 – User Request Workflow Diagram of GIC and Open Space Analysis Prototype

4.6.5 Study Area

4.6.5.1 This study area of this prototype covers Wan Chai, Central and Western DC and the relevant OZPs therein. Education facilities (i.e. nursery / kindergarten, primary and secondary schools), community care services facilities and public open space (local, district, and regional open space) are used to showcase the functionality of service area analysis.

District Councils	OZPs*
Central and Western* **Wan Chai***	Kennedy Town & Mount Davis (Plan Nos. S/H1/20, R/S/H1/20-A1, R/S/H1/20-A2) Pok Fu Lam (Plan No. S/H10/17) Mid-Levels West (Plan No. S/H11/15) Mid-Levels East (Plan No. S/H12/12) Jardine's Lookout & Wong Nai Chung Gap (Plan No. S/H13/12) The Peak Area (Plan No. S/H14/13) Aberdeen & Ap Lei Chau (Plan No. S/H15/33) Shouson Hill & Repulse Bay (Plan No. S/H17/13) Tai Tam & Shek O (Plan No. S/H18/10) Stanley (Plan No. S/H19/12) Chai Wan (Plan No. S/H20/23) Quarry bay (Plan No. S/H21/28) Central District (Extension (Plan No. S/H24/9) Wan Chai North (Plan No. S/H25/4) Sai Ying Pun & Sheung Wan (Plan No. S/H3/32) Peel Street/Graham Street (Plan No. S/H3/LDC4/2) Staunton Street/Wing Lee Street (Plan No. S/H3/URA1/4) Yu Lok Lane/Central Street Street (Plan No. S/H3/URA2/2) Queen's Road West/In Ku Lane (Plan No. S/H3/URA3/1) Central District (Plan No. S/H4/17) Wan Chai (Plan No. S/H5/28)

Table 4.8 – Study Area for Prototype

4.6.6 Functions

4.6.6.1 The prototype will demonstrate three main functions: generation of GIC tables, visualization of GIC facilities and open space and service area analysis.

4.6.6.2 Users can examine the spatial distribution of existing and planned GIC facilities / open space in an online map interface, assess the geographical service area of selected facilities within a district with a summarisation of servicing population. Additionally, users can simulate the change in provision requirements of GIC facilities an open space based on the change in population within a district as defined by HKPSG.

4.6.6.3 The functions delivered and tested in the prototype development process and to be included or requiring further development in the implementation stage are summarised in **Table 4.9**.

	Key Functions		Prototype Stage	Implementation Stage
i.	Generate GIC table	a. Select DCs / OZPs	- Delivered and tested - Included areas as listed in **Table 4.8** above	- The coverage will be extended to whole territory
		b. Input population	- Delivered and tested	- To be included
		c. Indicate the shortfall or surplus in GIC facilities / open space in accordance with HKSPG requirements	- Delivered and tested	- To be included
		d. Edit defaulted figures	- Delivered and tested	- To be included
		e. Display the GIC facilities / open space in the GIC table on a map interface	- Delivered and tested - GIC facilities and open spaces in areas as listed in **Table 4.8** above can be displayed	- The coverage will be extended to whole territory
		f. Export GIC table	- Delivered and tested	- To be included

	Key Functions		Prototype Stage	Implementation Stage
ii.	Visualize spatial distribution of GIC facilities and open space	a. Select types of GIC facilities / open space to display	- Delivered and tested - Available to select kindergarten / nursery, primary school, secondary school, day care centres for the elderly and open spaces to display	- All GIC facilities and open space will be included - Export in machine-readable formats for other analyses
		b. Select areas to display	- Delivered and tested - Available to select areas listed in **Table 4.8** above	- The coverage will be extended to whole territory
		c. Display information regarding selected GIC facilities / open spaces on map interface	- Delivered and tested - Information regarding GIC facilities in the area listed in **Table 4.8** above can be displayed - Information regarding open spaces across whole territory can be displayed	- All GIC facilities across the whole territory will be included - Real time information can be considered to incorporate
iii.	Enable service area analysis for GIC facilities and open space	a. Select district for analysis	- Delivered and tested - Available to select areas listed in **Table 4.8** above for analysis	- Can select all districts for analysis
		b. Select type of GIC facilities / open spaces for analysis	- Delivered and tested. - Available to select primary school, day care centres for the	- Can select all GIC facilities and open spaces for analysis - Can identify possible site for GIC facilities /

	Key Functions		Prototype Stage	Implementation Stage
			elderly and open spaces for analysis	open space on map for analysis
		c. Input walking distance / time for analysis	- Delivered and tested	- Can input travel distance / time by other modes of transportation for analysis

Table 4.9 – Functions of Application in Prototype and Implementation Stages

4.6.7 Data Requirement

4.6.7.1 Interfacing datasets used in this prototype, as well as suggested additional datasets subject to further review for implementation are listed in **Table 4.10**. During the future implementation stage, liaison and agreement with respective B/Ds on the use of the datasets in the application would be required.

B/Ds / Other Parties	Data / Dataset for this Application	Included in Prototype Stage	Included in Implementation Stage
LandsD	Digital Topographic Map iB1000, iB5000, iB10000, iB20000	Yes	Yes
	Digital Orthophoto DOP5000	Yes	Yes
CEDD	LiDAR Data (2011)	Yes	Yes
PlanD	OZP	Yes	Yes
	Land Supply Database	Yes	Yes
	WGPD data	Yes	Yes
	TPEDM data	Yes	Yes
	3D Photorealistic Mesh Model	Yes	Yes
	Open Space	Yes	Yes
	Facilities for the Elderly	Yes	Yes
	HKPSG	Yes	Yes
TD	Intelligent Road Network	Yes	Yes
C&SD	Population Census	Yes	Yes
	Population Projection	Yes	Yes
Hospital Authority	Real-time data such as government clinic waiting time	No	Yes
LCSD	Real-time data for availability of different recreational facilities	No	Yes

B/Ds / Other Parties	Data / Dataset for this Application	Included in Prototype Stage	Included in Implementation Stage
EDB	Number of classrooms and students	No	Yes
Various Public Transport Companies	Traffic information (e.g. bus stops, public transport routes)	No	Yes

Table 4.10 – Data Requirement of this Application

4.6.8 Scale up of the Application

4.6.8.1 This application can link up with other applications to broaden the functionality. For example, the site search result from Site Search application can be ed to this application for undertaking service area analysis to further assess the suitability of the site. The application can also integrate with Connectivity Analysis to check if the suggested location of the GIC facilities or open space is easily accessible and compatible with the pedestrian model.

4.6.8.2 Once the age structure per building block can be provided, more detailed service area analysis for different age groups can be carried out. For example, the spatial distribution of aged population (i.e. >65) within building blocks of an area or district can be displayed and crosschecked with the spatial distribution of existing and planned elderly friendly facilities to see if these facilities are accessible or placed in suitable location.

4.7 Connectivity Analysis

4.7.1 Background

4.7.1.1 The importance of POD has been recognized by the Government to improve and reinforce city attractiveness and citizen well-being.

4.7.1.2 In Chapter 11 (Urban Design Guidelines, section 6.2(5)) of HKPSG, it is mentioned that more pedestrian-oriented and pedestrian-interested space should be created in core areas in order to improve the streetscape.

4.7.1.3 According to the Chief Executive's 2017 (Clause 160) and 2018 (Clause 260) Policy Address, it is stated that over the years, it has been the Government's transport policy to develop Hong Kong into a walkable city. Implanting the concept of walkability, therefore, has been considered as a key transformation for city planning and design. New measures would be implemented along four themes:

i. "Make it smart" by providing user-friendly information on walking routes

ii. "Make it connected" by enhancing pedestrian networks

iii. "Make it enjoyable" by making walking a pleasant experience

iv. "Make it safe" by providing a safe and quality pedestrian environment"

4.7.1.4 In order to take forward the "Walk in HK" initiative and encourage people to walk more, the Government and academic have started to work on building a pedestrian-oriented environment.

4.7.1.5 Below are some ongoing works/studies relating to walkability and enhancement of pedestrian network being conducted by B/Ds and academics:

i. Under "Walk in HK" (https://walk.hk), TD has commenced various studies relating to walkability including a 30-month Consultancy Study on Enhancing Walkability in Hong Kong which commenced in December 2017. The study aims to explore different opportunities to enhance the walkability in Hong Kong from a holistic and strategic perspective, as well as to showcase innovative measures in two selected pilot areas (namely Central and Sham Shui Po) to create a comfortable walking environment. Other studies are being conducted in parallel such as the "Review of Assessment Mechanism for Hillside Escalator Links and Elevator Systems and Preliminary Feasibility Studies Hillside Escalator Links" to review and improve the assessment mechanism established by the Government in 2009, and on this basis to carry out initial screening and assessments for the new proposals received in past years to select the most feasible and justified proposals, so as to draw up a timetable for implementing these proposals in future.

ii. EKEO has been driving a pedestrian-oriented environment in Kowloon East by improving at-grade pedestrian environment in phases. The "Easy Walking" function in My Kowloon East (MyKE) mobile application provides a way-finding tool to cater for the needs and preferences of individual users, while the "Thematic Tour" and "Personalised Tour" functions make walking in Kowloon East more interesting. The walking route suggestion includes features specific to the district, enabling users to identify a walking route that is most suitable for their needs and preferences.

Indoor positioning devices have been installed in building passageways such as shopping centre in Kowloon Bay, making indoor positioning possible in MyKE. PoIs are also linked to the suggested walking route, according to personal preferences and interests, which is also available under "Personalised Tour". For Facebook users, the system uses AI to analyse users' Facebook posts for a more accurate personal recommendation.

iii. LandsD has started developing 3D pedestrian map to connect passageways at multi-level (i.e. elevated walkways, underpass, passage through buildings, etc) in various regions (e.g. Kwun Tong) across the territory to support various uses in future. Along with this, HKU has built a 3D pedestrian model in Central, in which passageways at multiple layers (at-grade pedestrian, underground walkway, above ground footbridges and connected walkways through buildings) have been connected. Under this model, the shortest / fastest path through can be found between the origin and destination. The current model, however, is just a "single line" model, in which attributes such as the effective dimensions, street furniture locations (e.g. street lamppost, fence, toilet, etc.) and pedestrian flow have yet to be included.

iv. HKUST and HKU has commenced a research study on "Strategies for Enhancing Walkability in Hong Kong via Smart Policies", funded by the Strategic Public Policy Research Funding Scheme, aims to investigate smart policy options through the use of walkability network platform and walking behaviour modelling to enhance walkability in Hong Kong. With the adoption of various walking attributes, including functional attributes, safety and security attributes, environmental and aesthetics attributes, walkability utility functions are determined, and hence effectiveness of walkability policies could be evaluated.[35]

4.7.1.6 Most of the current works for pedestrian walkways are "post-planning" which is remedial/retrofit in nature. In other words, the planning of pedestrian network/walkways is not accorded with priority in the whole planning process, and would only be taken into account when the planning of all major landuse has been in place. Also, there is a potential lack an integrated platform to provide a tool for analysing walkability and the pedestrian network with due regard to city/urban environment including street furniture, air quality, green areas, etc. Besides, there is currently a lack of baseline data (i.e. pedestrian flow, pedestrian model with dimensions and street furniture) to support the conducting of pedestrian flow/network assessment.

4.7.1.7 A general understanding for walking in Hong Kong is that the walkable distance for people is up to 400 m. As suggested by Audi et al[36], the city's confusing layout and unorganized street furniture may hinder citizens from walking. Furthermore, pedestrian routing and relevant walking experience were not prioritized in the planning stage and they would only be considered after all landuses and transportation network were decided. Consequently, a majority of Hong Kong people use public transportation daily, thus efficient and easy-to-navigate walking

[35] Lo H., Cheng J., Chiaradia A., Lau A., Wang G., Wu X. Strategies for Enhancing Walkability in Hong Kong via Smart Policies

[36] Michael Audi, Kathryn Byorkman, Alison Couture, Suzanne Najem. Measurement and Analysis of Walkability in Hong Kong. March 4, 2010.

routes to and from these stops, or between and along the harbour front and city hinterland, are extremely important.

4.7.2 Purpose

4.7.2.1 This prototype is to develop a connectivity analysis tool that allows B/Ds and consultants/contractors to share information, analyse, and display the pedestrian network and facilities in 3D environment for subsequent technical assessment to support landuse planning for walkability. The key objectives of this application are to:

- Provide a digital twin 3D model and 3D pedestrian map to visualize the walkability assessments and surrounding environment;
- Facilitate collaboration, collection and collation of baseline pedestrian model and related data for a more rigorous assessment for pedestrian planning and design;
- Provide a framework for B/Ds to share geospatial walkability context in form of a digital twin city;
- Provide a tool for users to conduct origin-destination pathfinding, walkability analyses and path analyses of a given route in Hong Kong based on the recent academic researches[37];
- Identify pain points based on walkability scoring to facilitate street design and provide an additional aspect for landuse planning considerations; and
- Facilitate comparisons between proposed connectivity options.

4.7.3 Benefits

4.7.3.1 With the implementation of this application, it is envisaged that the following benefits can be realized:

- Provide a tool for walkability assessments and to assess the pedestrian network with a 3D pedestrian network model in the process of landuse planning.
- Support pedestrian planning and improvement
- Facilitate decision making on planning of pedestrian network with support of landuses, 3D walkability environment and pedestrian flow data.
- Support end-user experience by providing visualization of a comprehensive pedestrian linkage network and surrounding areas.
- B/Ds involved in walkability assessments in planning and design stages can make use of the pedestrian model and related walkability analysis of this application to prepare for potential future PIA
- Academia can make use of the pedestrian model and walkability scoring system of this application for extended research and studies related to pedestrian network and walkability assessments.

[37] Refer to footnotes 39 and 40.

4.7.3.2 This application provides a robust tool for B/Ds to review the walkability in Hong Kong by measuring the walkability scores of different routes and help to identify the problematic areas for further modification and enhancement. The application could also interact with the public transport route analysis tool for a more comprehensive analysis, and the following analyses can also be conducted with the accurate data made available in the implementation stage:

- locations of public transport stops and pedestrian routing based on a given pedestrian flow;
- impact of construction sites on pedestrian flow and experience;
- influence of weather conditions on pedestrian flow and routing;
- pathfinding of the pedestrian routes regarding different personalized choices such as visual aesthetics, slope, night lighting, real-time pedestrian flow, etc.;
- indicating the need of handicap accessible routes regarding the density of pedestrians in need in adjacent areas; and
- indicating the need of seating areas regarding the pedestrian flow, and other factors.

4.7.4 System Design

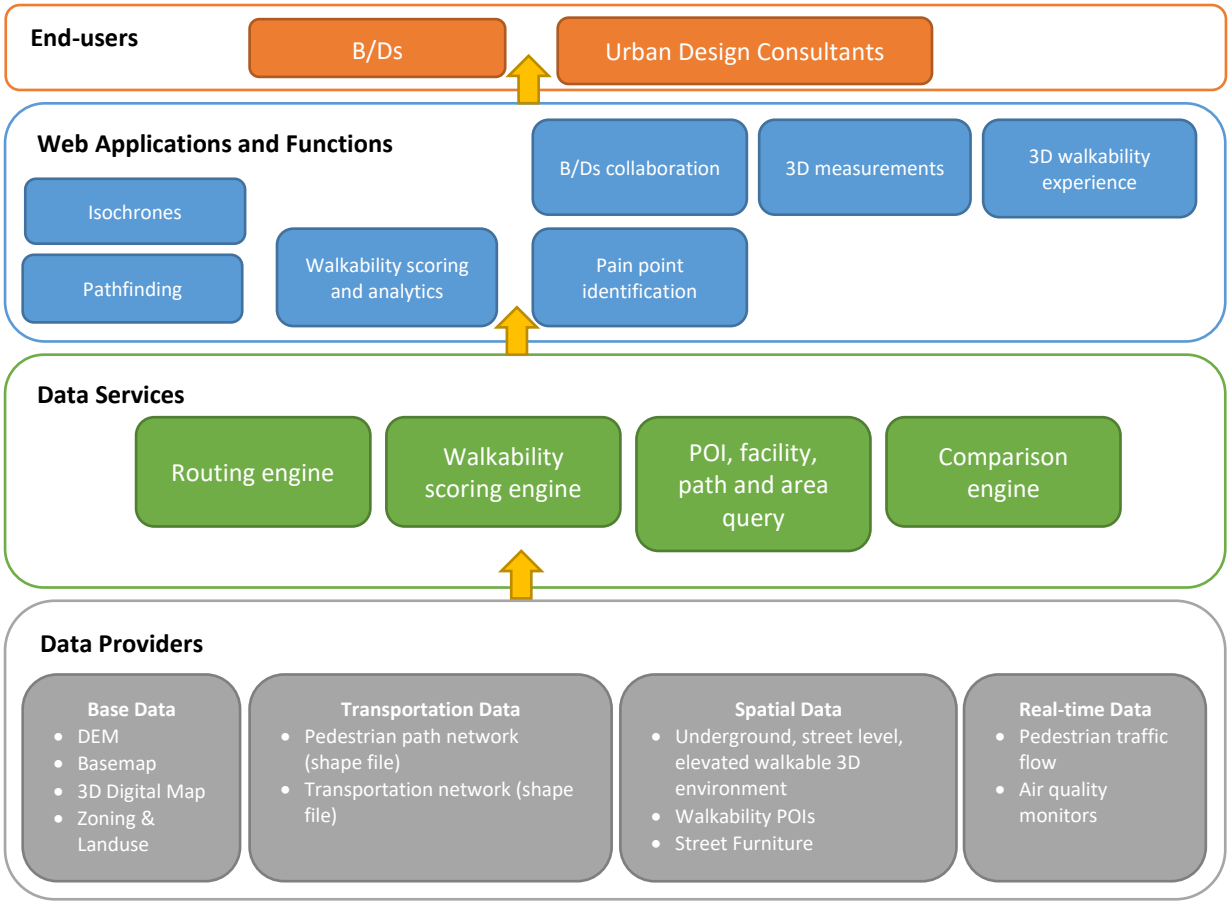


Figure 4.14 – Workflow Diagram of Connectivity Analysis Prototype

4.7.4.1 Technical infrastructure:

i. Software: The prototype is developed based on a proprietary software which provides web interface for the required functions. During the implementation stage, it is recommended to assess whether the proprietary or open source software is the most suitable technology for the application development.

ii. Hardware: The prototype is developed on a private cloud environment for short term demonstration purpose. It is recommended to have a setting of no less than 8 core 2.6GHz CPU and 64GB RAM for full implementation.

4.7.4.2 The application is undertaken by the following key steps (**Figure 4.14**):

i. The overall prototype development started by identifying and collecting necessary information for building a database for pedestrian walkability analysis. The data mainly consists of the base data for building the 3D virtual Hong Kong, transportation data in the form of comprehensive 3D pedestrian path and transportation networks; as well as spatial data including 3D street furniture, POIs, etc. Furthermore, real-time data, when ready, can also be adopted to enhance the completeness and decision-making.

ii. After collecting the required raw data, the raw data was possessed and transformed into 3D connectivity virtual twin for the use of this application. A several of mainstream functions including path-finding, visualizing of selected walking paths and POIs, walkability analysis, walkability comparison between different options and basic measurements could be conducted.

iii. Users in different B/Ds can make use of this application to test for walkability and preform relevant analysis ultimately.

4.7.5 Study Area

4.7.5.1 To demonstrate the feasibility of the prototype, a pilot test area in urban district was selected for reviewing the functions and processes of the aforesaid two aspects. Among all districts, it is considered that Central is comparatively suitable to serve as the testing area based on the following reasons: (1) pedestrian maps of this area have been made available from LandsD and HKU; (2) Central is traditionally regarded as the CBD in Hong Kong, the network connection is very complex as delineated in **Figure 4.15**, with a high economic activities and pedestrian flow, data/assessment results would be useful to enhance landuse planning of the area and (3) The 3D pedestrian map from LandsD and the results of the pedestrian flow level predictive model developed by HKU[38] were also available for Central which was also incorporated in the prototype to present the comprehensive situation of walkability in Central.

4.7.5.2 Besides, the following considerations have also been taken into account in selecting the testing area:

[38] Chiaradia, A., Zhang, L., Khakhar, S., Su, X., Cui, Y., Zhu, J., Tse, H. (2018), Walkable HK Central and Hong Kong, 3D indoor and outdoor pedestrian network. University of Hong Kong, Faculty of Architecture, DUPAD. Funded by HKU grants. V05.18.10.19.

- Central district is chosen as the study area for the connectivity analysis regarding proposals for Public Spaces and Walkability under Hong Kong 2030+ as an area connecting hinterland and harbour.
- Connaught Garden, IFC commercial complex area and Central MTR station form a typical scenario to demonstrate the pedestrian connections in 3 different levels: (1) at-grade pedestrian, (2) underground subway and (3) above ground footbridges and connected walkways.
- CCTV and IoT sensors are available in Central which can be made use of to support real-time pedestrian flow analyses in later stage.

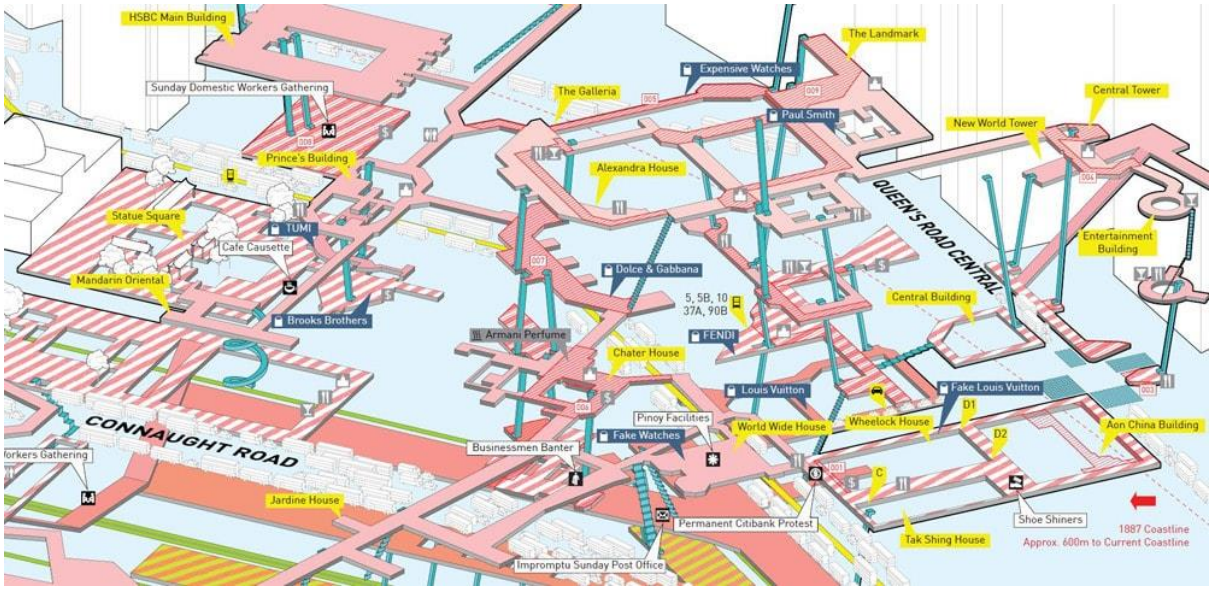


Figure 4.15 – Complexity of Pedestrian Passageways in Central[39]

4.7.6 Functions

4.7.6.1 The functions delivered and tested in the prototype development process and to be included or requiring further development in the implementation stage are summarised in **Table 4.11**.

	Key Functions		Prototype Stage	Implementation Stage
i	Visualization of 3D Pedestrian Network Model	a. Visualize 3D pedestrian network	- Delivered and tested	- Delivered and tested
		b. Fine-tune the features of the 3D pedestrian network model	- Delivered and tested - Edit street furniture in the application and compare the KPIs	- Automatic update information of shops and retail types at street level through data from MMS

[39] https://randomwire.com/hong-kong-city-without-ground/ from a book "Hong Kong – City Without Ground"

	Key Functions		Prototype Stage	Implementation Stage
ii	Origin-Destination preference route finding and isochrones	a. Calculate different preference routes with different modes of transportation	- Delivered and tested - Select the shortest path in Central and WanChai district by walking	- Extend the coverage to the remaining areas, following the production of 3D pedestrian map of LandsD - Identify paths based on preference - Incorporate multiple transport modes - Select multiple points on the map - Include real-time status of pedestrian facilities and IoT data
		b. Calculate isochrones in different origins with multiple distance and speed	- Delivered and tested - Calculate one isochrone with defaulted travelling speed	- Further refine to show the isochrones with multiple distance and speed
iii	Walkability scoring	a. Incorporate walkability scoring formula	- Delivered and tested - Include simplified scoring methodology based on recommendations from a previous study of walkability in Hong Kong[40]	- Include different walkability scoring formulas - Calculate the walkability scores for multiple routes or for a whole area - Prepare for PIA
iv	Pain points identification	a. Overlay OZP layer with pedestrian flow model	- Delivered and tested - OZP layer is overlaid with pedestrian flow model results[41] in Central district	- Incorporate real-time pedestrian flow and related attributes through surveillance cameras and video analytics to provide a more comprehensive

[40] Michael Audi, Kathryn Byorkman, Alison Couture, Suzanne Najem. Measurement and Analysis of Walkability in Hong Kong. March 4, 2010.

[41] Chiaradia, A., Zhang, L., Khakhar, S., Su, X., Cui, Y., Zhu, J., Tse, H. (2018), Walkable HK Central and Hong Kong, 3D indoor and outdoor pedestrian network. University of Hong Kong, Faculty of Architecture, DUPAD. Funded by HKU grants. V05.18.10.19.

	Key Functions		Prototype Stage	Implementation Stage
			- Identify possible facilities to be replaced and relocated to other desirable locations	analysis, subject to further studies
		b. Predict change in pedestrian flow	- Not yet included due to pedestrian flow model is not ready.	- Once real time pedestrian flow model is ready and be incorporated into the application, it can show the proposed impacts on the pedestrian flow from different constructions.
v	Collaborate and co-operate with other parties	a. Mark comments on selected routes or areas	- Delivered and tested	- To be included
		b. Export excel files showing different KPIs	- Delivered and tested	- To be included
		c. Collaborate with other studies	- Delivered and tested	- To be included

Table 4.11 – Functions of Application in Prototype and Implementation Stages

4.7.7 Data Requirement

4.7.7.1 Interfacing datasets used in this prototype, as well as suggested and additional datasets subject to further review for implementation are listed in **Table 4.12**. In future implementation stage, further liaison and agreement with respective B/Ds on the use of the datasets in the application would be required.

B/Ds / Other Parties	Data / Dataset for this Application	Included in Prototype Stage	Included in Implementation Stage
LandsD	Digital Topographic Map iB1000, iB5000, iB10000, iB20000	Yes	Yes
	GeoReference Data iG1000	Yes	Yes
	Digital Orthophoto DOP5000	Yes	Yes
	GeoCommunity Database (i.e. schools, community facilities, etc.)	Yes	Yes

B/Ds / Other Parties	Data / Dataset for this Application	Included in Prototype Stage	Included in Implementation Stage
	3D Spatial Data (i.e. Buildings, Roads, Terrain, etc.)	Yes	Yes
	Railway Station	Yes	Yes
	Waterfront	Yes	Yes
	3D Pedestrian Network Model	Yes	Yes
CEDD	LiDAR Data (2011)	Yes	Yes
PlanD	OZP	Yes	Yes
	3D Photorealistic Mesh Model	Yes	Yes
TD	Intelligent Road Network	Yes	Yes
	Traffic signs	No	Yes
	Pedestrian directional signs	No	Yes
	Traffic light timing	No	Yes
	CCTV footage	No	Yes
TMO	Available tree data collected for the purpose of Tree Risk Assessment for trees located in Category 1 zone	Yes	Yes
HKU	Pedestrian flow prediction model	Yes	Yes
ArchSD/ CEDD/ DSD/ EMSD/ WSD	Construction sites information (if any)	No	Yes
EMSD	Escalator, Elevator, etc.	No	Yes
HyD	Pedestrian road railing	No	Yes
	Approved excavation permits	No	Yes
	Street lighting	No	Yes
OGCIO	IoT sensors	No	Yes

Table 4.12 – Data Requirement of this Application

4.7.8 Scale up of the Application

4.7.8.1 In future, both the walkability analysis and pedestrian network model can be further enhanced by incorporation of more static and dynamic IoT data such that a robust model for pedestrian analysis to support planning and design. With a robust and comprehensive pedestrian flow model, PIA may possibly be conducted to assess if there are any insurmountable impacts on the existing pedestrian network from a proposed development, and suggest if any mitigation measures are required.

4.7.8.2 With the support of surveillance cameras, real-time pedestrian flow data could be incorporated in this application to facilitate real-time walkability analysis, and enable a dynamic reaction to the changing pedestrian flow which can be used in urban management.

4.8 Visualization and Analysis of Underground Space and Utilities

4.8.1 Background

4.8.1.1 Hong Kong has encountered land supply shortage problems for years. Underground space is a viable source of land supply, and good underground planning and development could help relieve the pressure on land supply for above ground development. Although underground development is recognized as more complex and costlier, it offers an alternative for developments in Hong Kong.

4.8.1.2 Over the past years, the Government has conducted strategic studies such as "Long Term Study for Cavern Development" and "Territory-wide Study on Underground Space Development in the Urban Areas of Hong Kong" to identify potential sites for underground development in Hong Kong. Based on the results of these studies, in June 2015, the Government had also commissioned the "Pilot Study on Underground Space Development in Selected Strategic Urban Areas" covering four selected Strategic Urban Areas (SUAs), namely TSTW, Causeway Bay and Happy Valley, and Admiralty/Wan Chai. The Study aims to identify the potential for underground space developments in each of these areas and to formulate Underground Master Plans to guide the future underground space development.

4.8.1.3 As a whole, Hong Kong is currently harnessing opportunities of utilising underground space to achieve three key objectives:

- The first objective relies on enhancing living environment: underground spaces can be used to relocate existing above ground facilities, thereby releasing the valuable surface land for more beneficial and compatible landuses.
- The second objective aims to improve pedestrian connectivity with underground spacing connecting buildings and development creating additional passageways to relieve the congested pedestrian and traffic situation at above-ground as well as providing all weather and seamless pedestrian connection.
- The last objective targets to create new space for uses beneficial to communities such as commercial, recreational, art and community facilities, etc. In the past few years, studies such as "Cavern Master Plan", "Territory-wide Study on Underground Space Development to properly address the complexity of this new challenges, new tool and applications would be useful to support the underground master plan development.

4.8.1.4 In conjunction with the ongoing development of Underground Masterplan Plans for the four SUAs, underground utility is also a key component of underground space. Currently, Utilities Undertakers (UUs) in both government and non-government organisations use EMPC to circulate the mark plant information in an electronic way prior to the application of road excavation permit. The EMPC is a computer system used by UUs to make query on existing utilities for a particular area that are managed by different UUs. The query was made and circulated through the computer system but the information received are often adopted in non-spatial format such as PDF and JPEG. Each UUs manage their own asset and there is a lack of a common platform that allows UUs to quickly visualize the actual situation of underground utilities and structure. Other than EMPC, under current

practice, XPMS managed by HyD is a platform for UUs to apply excavation permit, in which some underground utilities related information such as excavation plans and extents would be available. These excavation related data/information would also be useful for development of this application.

4.8.2 Purpose

4.8.2.1 The application is to provide a common collaborative 3D underground space and utility platform for B/Ds to:

- Visualize the existing underground space development, underground structure, utility network and utility tunnels owned and managed by different B/Ds, MTR and utilities/telecom companies;
- Allow B/Ds to view the underground network in 2D and 3D environment to facilitate underground space/cavern planning;
- Allow B/Ds to review, comment and annotate in a 3D context to facilitate underground space/cavern planning;
- Identify requirements for 3D utility data for mapping, urban planning, and excavation application administrations, taking into account the current setup and inputs from key stakeholders; and
- Recommend best practice from survey to 3D mapping of existing utility network, and ways of improving current platform (i.e. EMPC) to support underground data sharing and utilization.

4.8.3 Benefits

4.8.3.1 With the implementation of this application, it is envisaged that the following benefits can be realized by B/Ds and UU:

- Provide a collaborative platform for B/Ds to use the most updated underground information.
- Provide underground digital twin with a single source of truth data for use of B/Ds.
- Increase transversal visibility from initial planning to execution.
- Streamline the process of data acquisition among involved stakeholders.
- Enable a more robust and reliable engineering design together with a more accurate implementation programme by performing occupancy ratio assessment and clash analysis during planning and design stages before excavation takes place to ensure that there is enough underground space for installing the proposed underground utilities among the existing underground utilities.
- B/Ds involved in underground space and utilities assessments can use in planning, design and operational stages.
- UU – visualization and provision of comments.

4.8.4 System Design

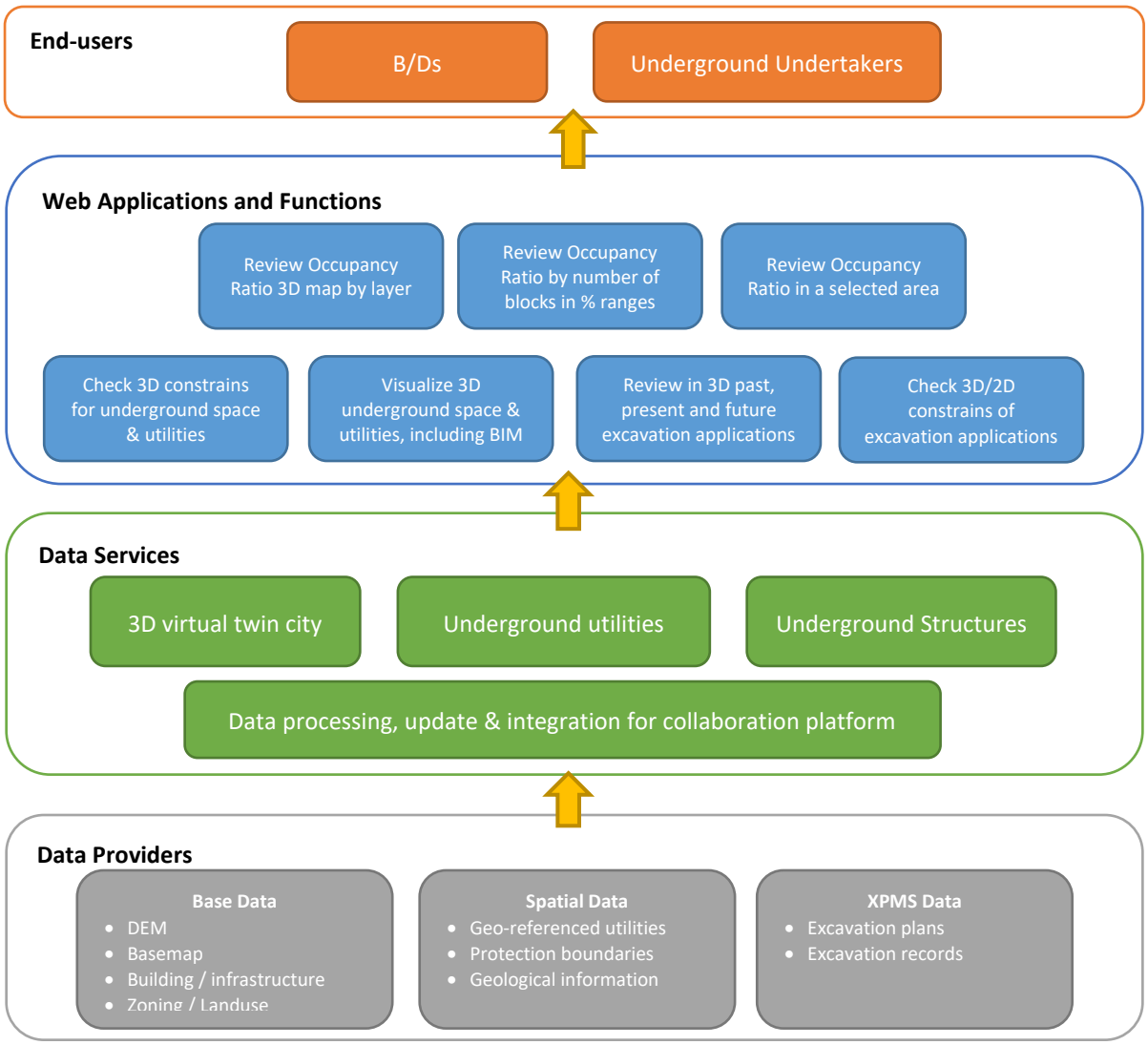


Figure 4.16 – Workflow Diagram of Visualization and Analysis of Underground Space and Utilities

4.8.4.1 Technical infrastructure:

i. Software: The prototype is developed based on a proprietary software which provides web interface for the required functions. During the implementation stage, it is recommended to assess whether the proprietary or open source software is the most suitable technology for the application development.

ii. Hardware: The prototype is developed on a private cloud environment for short term showcase. During the implementation stage, hardware requirment with the setting of 8 core 2.6GHz CPU (or above) and 64GB RAM (or above) is recommended for smooth operation of this application.

4.8.4.2 The application is undertaken by the following key steps:

i. The application will collect underground utilities information from different B/Ds and various utilities undertakers to formulate a 3D underground model

for the visualization of the underground utilities network, the underground structures, building foundations, relevant geological information, etc. Once the 3D underground model is formed, this application can mainly serve the following functions: underground space planning, underground occupancy assessment and underground utilities planning. Details of the workflow are set out in **Figure 4.16** above.

ii. When users have a proposal to lay a new underground pipeline, users can import the proposed alignments to the platform and perform underground occupancy ratio and clash analysis. Users can also retrieve similar and past applications via the platform for reference.

iii. When the excavation permit is issued under XPMS and the subsequent works have been completed by the project proponents in accordance with the approved alignments, the latest drawings of the newly laid pipeline alignments can be uploaded to the platform to keep up the 3D underground model up-to-date.

iv. If discrepancies between as-built situation and the 3D underground model are found on-site, users should record the as-built conditions and update the 3D underground model via the platform accordingly.

4.8.5 Study Area

4.8.5.1 The scope of this prototype is to develop a 3D digital platform to support data collection, visualization and related analysis of both underground space development and the peripheral underground utility.

4.8.5.2 The prototype is built by making reference to the "Pilot Study on Underground Space Development in Selected Strategic Urban Areas", in which Tsim Sha Tsui was identified as one of the Strategic Urban Areas for underground development. Upon consideration of currently available data including underground utilities, initial underground planning design with layout and underground configuration, etc., it is suggested to select the underground space beneath Kowloon Park in TSTW as the testing area for prototype development shown in **Figure 4.17**.

4.8.5.3 Besides, the following considerations have been taken into account in selecting the testing area:

- The underground space of Kowloon Park is located adjacent to nearby underground pathway and railway tunnel.
- Busy major roads surround the underground space of Kowloon Park: Nathen Road, Austin Road, Canton Road.
- Crowded pedestrian links provide a suitable location to demonstrate the interface between underground utilities, underground space as well as above ground planning.

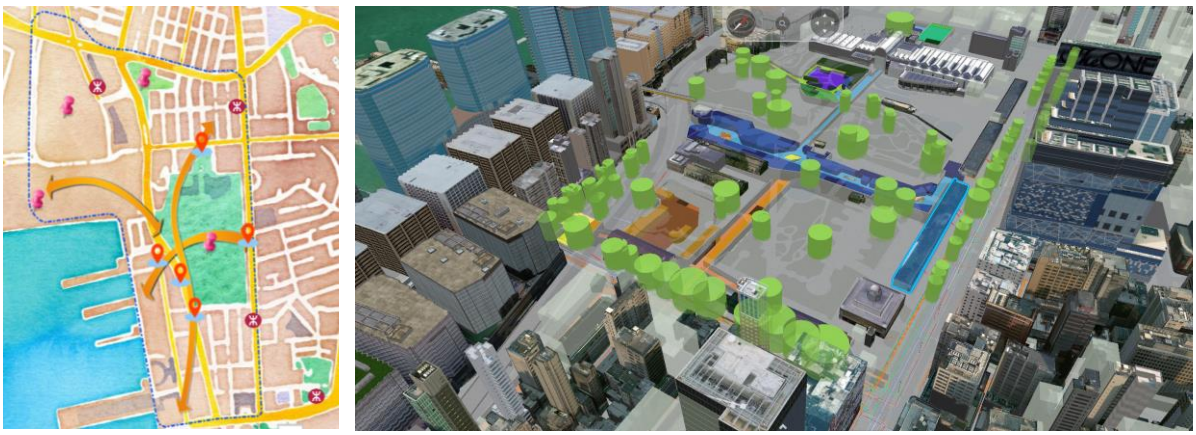


Figure 4.17 - Study Area of this Prototype - Boundary of Tsim Sha Tsui West UndergroundSpace Development (left) and Kowloon Park (right)

4.8.5.4 The prototype can support B/Ds to view the underground plan and surrounding urban environment of TSTW, and review the underground projects such as utilities capacity enhancement, underground space utilization improvement and underground connections development. With the incorporation of underground space and utilities and related information, the prototype could help to check and review the compatibility of the existing and planned underground facilities and developments, as well as the functionality and practicability of the underground space plan.

4.8.6 Functions

4.8.6.1 Potentially, users can check the proposed underground space design with the 3D underground model to see if the proposed design can be well connected with the surrounding building and / or railway stations. Moreover, the geological information can also be used to show the extent of land excavation work required if the proposed underground space design is implemented.

4.8.6.2 The functions delivered and tested in the prototype development process and to be included or requiring further development in the implementation stage are summarised in **Table 4.13**.

	Key Functions		Prototype Stage	Implementation Stage
i.	Underground 3D navigation	a. Visualize the underground data/ information in 3D environment	- Delivered and tested	- To be included
		b. Perform basic measurement and functions	- Delivered and tested	- To be included

	Key Functions		Prototype Stage	Implementation Stage
ii	Underground space planning	a. Examine constraints of underground development	- Delivered and tested (Underground constraints near the study area have been incorporated)	- To be included
		b. Identify possible development space	- Delivered and tested	- To be included
		c. Import of proposed development design	- Delivered and tested (The 3D model of SUAs in TSTW near Kowloon Park has been incorporated)	- To be included
iii	Underground utilities planning	a. Consolidate underground utilities information into one single platform	- Delivered and tested (Underground information in TSTW area near Kowloon Park and related information from XPMS have been incorporated)	- Extend the digital data of underground utilities to the whole territory.
		b. Perform underground occupancy assessment	- Delivered and tested (Based on sample underground utility data gathered from HyD and other relevant parties, occupancy heat map of the underground utilities for the study area has been presented)	- To be included - Allow more customisation on presentation of heat map

	Key Functions		Prototype Stage	Implementation Stage
		c. Import 3D model of proposed underground utilities for clash analyses	- Visualize the impact of the proposed underground utilities to other existing ones in 3D environment - Check any potential clashes	- To be included - Detect the clashes automatically - Suggest alternative clash-free routing
iv	Review Platform	a. Provide comments on underground space and utilities and export in different formats	- Delivered and tested	- To be included

Table 4.13 – Functions of Application in Prototype and Implementation Stages

4.8.7 Data Requirement

4.8.7.1 Interfacing datasets used in this prototype, as well as suggested and additional datasets subject to further review for implementation are listed in **Table 4.14**. In future implementation stage, further liaison and agreement with respective B/Ds on the use of the datasets in the application would be required.

B/Ds / Other Parties	Data / Dataset for this Application	Included in Prototype Stage	Included in Implementation Stage
LandsD	Digital Topographic Map iB1000, iB5000, iB10000, iB20000	Yes	Yes
	Digital Orthophoto DOP5000	Yes	Yes
	3D Spatial Data (i.e. Buildings, Roads, Terrain, etc.)	Yes	Yes
PlanD	Proposed Tsim Sha Tsui Strategic Underground Area	Yes	Yes
	3D Photorealistic Mesh Model	Yes	Yes
TMO	Available tree data collected for the purpose of Tree Risk Assessment for trees located in Catergory 1 zone	Yes	Yes
HyD	Excavation plans and extents from XPMS	Yes (One excavation case in Tsim Sha Tsui)	Yes

B/Ds / Other Parties	Data / Dataset for this Application	Included in Prototype Stage	Included in Implementation Stage
CEDD	Air raid tunnels	Yes	Yes
	LiDAR Data (2011)	Yes	Yes
	Ground water level	No	Yes
	Underground caverns	No	Yes
	Soils by type	No	Yes
DSD	Drainage	Yes	Yes
WSD	Water mains	Yes	Yes
CLP	Electricity	Yes	Yes
Towngas	Gas mains	Yes	Yes
Telecommunications UU	Telecommunications	Yes	Yes
Cable TV UU	Cable TV	Yes	Yes
Arup	Rockhead surface	Yes	Yes
MTR	MTR protection boundaries	Yes	Yes
	Tsim Sha Tsui MTR station	Yes	Yes
UUs	Various underground utilities	No	Yes
Other stakeholders or relevant B/Ds	Building foundations	Yes	Yes

Table 4.14 – Data Requirement of this Application

4.8.8 Scale up of this Application

4.8.8.1 Availability of accurate and digitized underground utility records of UUs is a precondition for further development or scaling up of this application. Without utility records of such quality, scaling up of this application would be considered as pre-mature.

4.8.8.2 With the establishment of data standards for the underground utilities such as the format of drawing and alignments, this application can be scaled up to cover all underground UUs and telecoms.

4.8.8.3 This application can be linked with the other systems, such as XPMS, for the workflow of application of excavation permits, including clash analysis of proposed utilities with existing underground constraints, and the subsequent action of application for road blockage for underground works implementation.

4.8.8.4 Ultimately, other underground spaces could be added, including building basement, piles, underground railway tunnels, railways stations, caverns, etc., to reflect the real underground situation of Hong Kong.

4.9 Compliance Checking of Building Plans

4.9.1 Background of the Application

4.9.1.1 The building design and construction process is conditioned by numerous regulations, conditions and assessment measures. These "rules" are continuously expanding in their requirements, and incorporating a huge amount of data that needs to be rigorously dealt with, in order to check compliance and assess the building performance. BIM technology is currently a key lever to accelerate productivity in the building and construction sector. With such tool, building compliance and performance can be assessed and simulated digitally. Design conflicts can be resolved before the construction stage, decreasing the rework cost and delay.

4.9.1.2 Since 1 January 2018, capital works projects with project estimates more than HK$30 million have been adopting BIM technology. BIM enables better control of the construction process and enhance cross-disciplinary collaboration, internal coordination, external communication, problem solving, decision-making support, productivity management and risk management.

4.9.1.3 BD has been developing an ESH for centralized processing of electronic submissions of building plans and documents, as well as other applications under the Buildings Ordinance. For each building plan submission, different B/Ds are involved to ensure compliance with related ordinances, regulations, conditions and requirements as stipulated. Similar works have been done overseas, such as the automated plan submission cum checking systems developed by Singapore Building and Construction Authority that facilitates electronic submissions, processing and approval of building project documents over the internet[42].

4.9.1.4 The current practice for building plan checking is done manually, extensive effort and resources are required for the manual checking process of the building plans against relevant regulations.

4.9.1.5 Also, there is a lack of interoperability between BIM and regulations compliance checking tools. With the implementation of ESH and new technologies in the coming future, it is anticipated that the development of (semi)automation compliance checking will be inevitable at various stages of building approval process in face of the ICT trends.

4.9.2 Purpose

4.9.2.1 The purpose of this prototype is to support extraction of the necessary data automatically from the BIM model prepared for building plan submissions for compliance checking against the prevailing regulations such as statutory planning and fire safety requirements. The key objectives are to:

- Visualize the proposed developments in 3D environment;
- Extract the necessary data automatically from the BIM projects for compliance checking against the prevailing regulations such as statutory planning and fire safety requirements;

[42] https://www.bca.gov.sg/newsroom/others/pr101000.pdf

- Highlight or give alert to potential violation of guidelines/requirements; and
- Enhance compliance checking process and save time in manual checking.

4.9.3 Benefits

4.9.3.1 With the implementation of this application, it is envisaged that the following benefits can be realized:

- A single platform to visualize building plans in BIM format and easily extract required information for vetting process.
- Improve and facilitate compliance checking process and save time in manual checking.
- Encourage the greater and fuller use of BIM technology.
- Environmentally friendly workflow by reducing the use of papers.
- Facilitate B/Ds to conduct preliminary compliance checking in the building plan approval process.
- Facilitate industry to undertake preliminary checking of the BIM models against any potential violation of regulations.

4.9.4 System Design

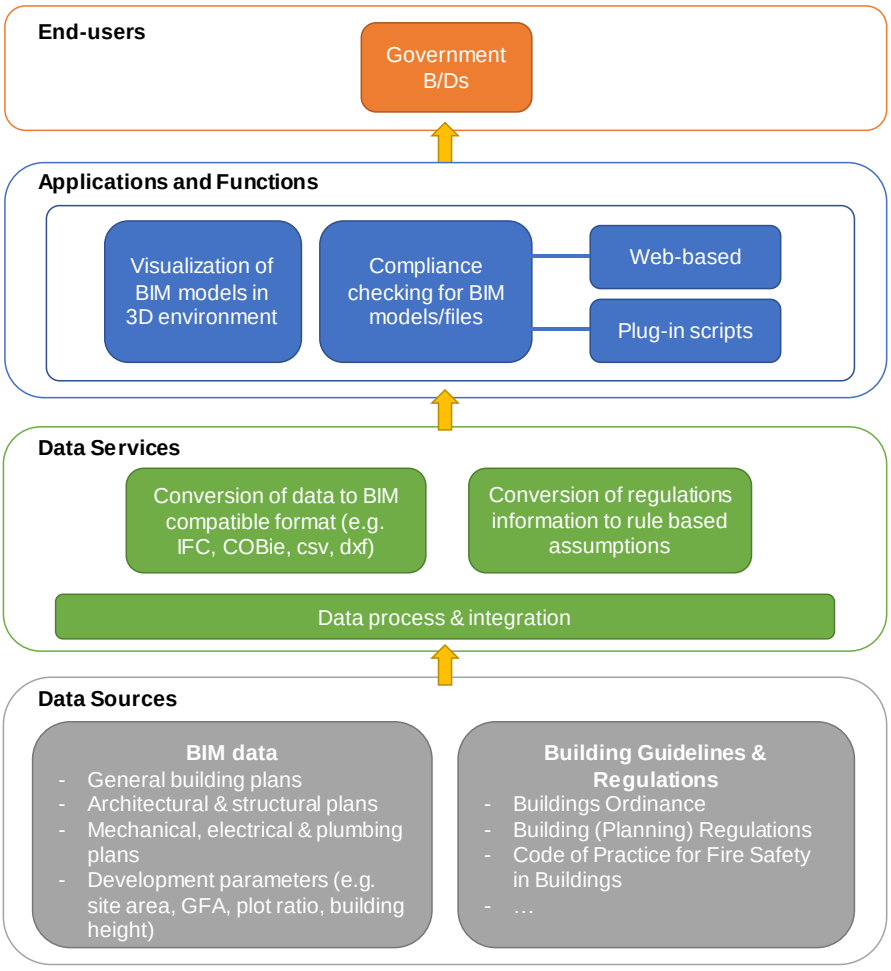


Figure 4.18 – Workflow Diagram of Compliance Checking of Building Plans

4.9.4.1 Technical infrastructure:

i. Software: The web-based application is developed with multiple software including Supermap and ArcGIS, while the BIM model and plug-in scripts are built with Autodesk Revit and Dynamo respectively.

ii. Hardware: Hybrid on-premise and cloud-based storage and Cesium web mapping service are adopted for online hosting GIS application to perform different functions. Implementation of the application would require 8 core 2.6GHz CPU (or above) and 64GB RAM (or above) for smooth operation of functions. Future scale up of the application would need to increase capacity for database, linkage with other built environment data and applications.

4.9.4.2 The application will be developed with a set of regulatory requirements in textual formats, which will then be converted into rule-based assumptions. Necessary data from the building plans in BIM formats will also be processed intelligently into other BIM-compatible formats to proceed to compliance checking. The key steps for undertaking automated compliance checking via this application include:

- The application will provide a web-based 3D digital twin for visualizing the BIM model for users to compare the proposed development against its surrounding environment. Models and polygons of the surroundings embedded with development information will also be displayed for users to check the compatibility of the subject proposal.
- Compliance checking analysis will be performed on a web-based application where the BIM-compatible data extracted from the BIM models or building plans in BIM format will be uploaded to check against with the regulatory requirements under prevailing guidelines, ordinances or regulations formulated into rule-based assumptions.
- After the BIM models or other machine-readable files derived from the BIM models have been uploaded onto the web-based application, the development parameters and relevant data will then be transformed into prescribed forms and tables.
- Regulatory requirements, such as statutory planning restrictions and lease requirements, will be converted into rule-based assumptions and checked against with the extracted development parameters of the uploaded project. If the project is subject to any other approvals, such as s.16 planning applications, its parameters will also be compared against the approved parameters that can be retrieved from relevant database linked to the application for compliance checking. Any discrepancies will be highlighted by the application for users' reference.
- On the other hand, the application also provides a download area for checking of BIM models with higher level of details, against regulations and guidelines on fire safety, structure and electrical and mechanical installations, etc. Plug-in scripts developed from programming tools, such as Dynamo (i.e. a visual programming language extension that works with Autodesk Revit software), can be downloaded to be used as a BIM checker to work with desktop BIM software, such as Autodesk Revit. Any non-compliance areas will be highlighted directly on the BIM models for users' easy references.

4.9.5 Study Area

4.9.5.1 This prototype will demonstrate automated compliance checks on digital building plans in BIM formats or other file formats derived from BIM models. Building regulations and codes will be converted into BIM-compatible rules for regulatory compliance analysis against the parameters from the BIM model.

4.9.5.2 In general, a project involves submissions of different types of plans (e.g. demolition plans, superstructure plans and drainage plans, etc.) to the Building Authority for approval. Among them, the general building plans (GBP) form the basis for the development of the detailed design of other types of plans, which are therefore used for demonstration in this prototype. Besides, in view of the diversified and complex regulations to be complied with in the submission of GBPs, focus will first be placed on statutory planning restrictions and fire safety in the prototype.

4.9.5.3 A BIM project of King Tai Court that is developed under Hong Kong Housing Authority in San Po Kong has been developed in Autodesk Revit format and used as a sample case for demonstration in the prototype. As the sample case was also subject to an approved s.16 application (No. A/K11/211), a database with approved s.16 planning applications was also linked to the prototype for demonstration.

4.9.5.4 For the web-based application, statutory planning restrictions were checked against with the sample BIM project. Required information from the BIM model is extracted and outputted into a prescribed table. The prototype also checked the extracted parameters against corresponding statutory planning restrictions, such as the maximum building height and plot ratio that could be retrieved from the s.16 planning applications database.

4.9.5.5 For the download area of plug-in scripts, since the sample BIM model was built with Autodesk Revit software, scripts for compliance checking of regulations were written with Dynamo, an open source visual programming tool to develop the compliance checking plug-in to work with Autodesk Revit. To check against the fire safety requirements, relevant requirements from "Means of Escape" prescribed in Code of Practice for Fire Safety in Buildings 2011 were chosen for demonstration, including the checking of headroom and any absence of exit and directional signs along the exit routing. The calculation of Usable Floor Space (UFS) as stipulated in the Building (Planning) Regulations is also taken for demonstrating the vetting of one of the fire safety requirements of a proposed project.

4.9.6 Functions

4.9.6.1 The functions delivered and tested in the prototype development process and to be included or requiring further development in the implementation stage are summarised in **Table 4.15**.

	Key Functions		Prototype Stage	Implementation Stage
i.	Visualization of BIM models in 3D environment	a. Allow uploading of BIM files and relevant documents for 3D web-based visualization	- Partially delivered and tested - View 3D models online which can only be uploaded through back-end services.	- Allow uploading the BIM model in neutral format, such as IFC formats, through front-end interface
		b. Visualize 3D models and relevant information of the surrounding environment to check the compatibility of projects	- Partially delivered and tested - Visualize site polygons with the corresponding site information and surrounding environment.	- Visualize the proposed projects on the realistic 3D model to form a 3D digital twin
ii	Compliance checking with web-based application	a. Allow uploading BIM files for data extraction	- Partially delivered and tested - Allow uploading building plans in DXF format and BIM schedule in CSV format for planning data extraction	- Allow uploading BIM files embedded with machine-readable and pre-defined parameters for data extraction, or other BIM compatible files
		b. Extract and export relevant prescribed parameters from the submitted BIM project into prescribed forms and tables for operational needs and vetting uses	- Partially delivered and tested - Include extraction of textual schedule in CSV or DXF formats, which can be displayed in a prescribed table for statutory planning checking	- Extract relevant data and parameters directly from project files in BIM formats. - Allow transforming the parameters into different forms and tables defined by the users for other checking purposes - Allow exporting and downloading the forms / tables

	Key Functions		Prototype Stage	Implementation Stage
		c. Visualize and search for relevant documents on the platform and retrieve relevant information and requirements from corresponding approval documents related to the subject case	- Delivered and tested - Link to an approved s.16 planning applications database for direct retrieval of and comparison with the parameters of the approved planning application	- Link up relevant databases and map layers for direct retrieval and checking of other building related information, e.g. PlanD's other statutory planning restrictions as stipulated in OZP.
		d. Check the parameters against regulatory requirements from various regulations and approved cases for different types of building plan submissions including GBPs, drainage plans and superstructure plans, etc., and show alert and highlight potential violation of guidelines / requirements	- Partially delivered and tested - Indicate discrepancies in parameters	- Highlight discrepancies on the BIM model - Include more regulations and standards (e.g. OZP, SBD guidelines and other codes of practices) for checking - Extend to check other types of building plans, such as drainage and superstructure plans, etc.
iii	Compliance Checking with plug-in scripts	a. Download plug-in scripts to extend its use in BIM software for checking of proposed buildings against regulations	- Delivered and tested (Only Using Autodesk Revit Plug-in Dynamo)	- Include more plug-in scripts which can be extended to work with technology neutral BIM files. (i.e. Autodesk Revit Plug-in Dynamo)

	Key Functions		Prototype Stage	Implementation Stage
		b. Allow checking the BIM project against guidelines / requirements in the BIM software using the plug-in scripts	- Delivered and tested	- To be included - Extend the compliance checking against other fire safety requirements and restrictions other than fire safety - Extend to check other types of building plans such as drainage and superstructure plans, etc.
		c. Show alert and highlight on potential violation of guidelines / requirements in the BIM project file after running the plug-in scripts	- Delivered and tested - Allow highlighting potential violation	- To be included

Table 4.15 – Functions of Application in Prototype and Implementation Stages

4.9.7 Data Requirement

4.9.7.1 Interfacing datasets used in this prototype, as well as suggested and additional datasets subject to further review for implementation are listed in **Table 4.16**. In future implementation stage, further liaison and agreement with respective B/Ds on the use of the datasets in the application would be required.

B/Ds / Other Parties	Data / Dataset for this Application	Included in Prototype Stage	Included in Implementation Stage
LandsD	Digital Topographic Map iB1000, iB5000, iB10000, iB20000	Yes	Yes
	Digital Orthophoto DOP5000	Yes	Yes
PlanD	Database of s.16 planning applications	Yes	Yes
B/Ds / developers / contractors	BIM models	Yes (Sample public housing project (King	Yes

B/Ds / Other Parties	Data / Dataset for this Application	Included in Prototype Stage	Included in Implementation Stage
		Tai Court) from HD)	

Table 4.16 – Data Requirement of this Application

4.9.8 Scale up of the Application

4.9.8.1 In future, more regulations and standards (e.g. SBD guidelines and other codes of practices, etc.) can be explored and processed into rule-based assumptions through an established system, which can be applied to check against other types of plans such as superstructure and drainage plans.

4.9.8.2 This application can directly link to PlanD database to extract necessary information from all approved s.16 planning applications. Subsequently, the automatic compliance checking tool can compare and check extracted information from BIM submissions against the approved conditions. Additionally, GBPs of the BIM projects can also be used to test against the statutory planning restrictions set out in the OZP.

4.9.8.3 When the technology evolves and becomes mature, the tools developed for various types of plans could be possibly integrated into the ESH to facilitate the building approval process upon further discussion with relevant B/Ds. In addition, BIM models can also be accumulated for development of the 3D digital twin.

4.10 Visualization and Analysis of Urban Green Infrastructure

4.10.1 Background of the Application

4.10.1.1 Trees in Hong Kong are managed and maintained by various departments according to the tree location. For instance, HyD is responsible for the management of trees within the boundary of the slopes and expressways maintained by HyD while HD is responsible for trees inside public housing area. Additionally, individual departments have their own intranet web-based platform for their own tree/vegetation management, which interfaces with TMIS e.g. HyD has a VIS, LCSD has a TDBS2 GIS platform for their staff to update tree information, etc.

4.10.1.2 Currently, the TMIS is managed by TMO under DEVB with the participating departments including ArchsD, CEDD, HD, HyD, AFCD, LCSD, DSD and WSD (**Figure 4.19**). It serves as a common platform in support of TRA for tree management departments.

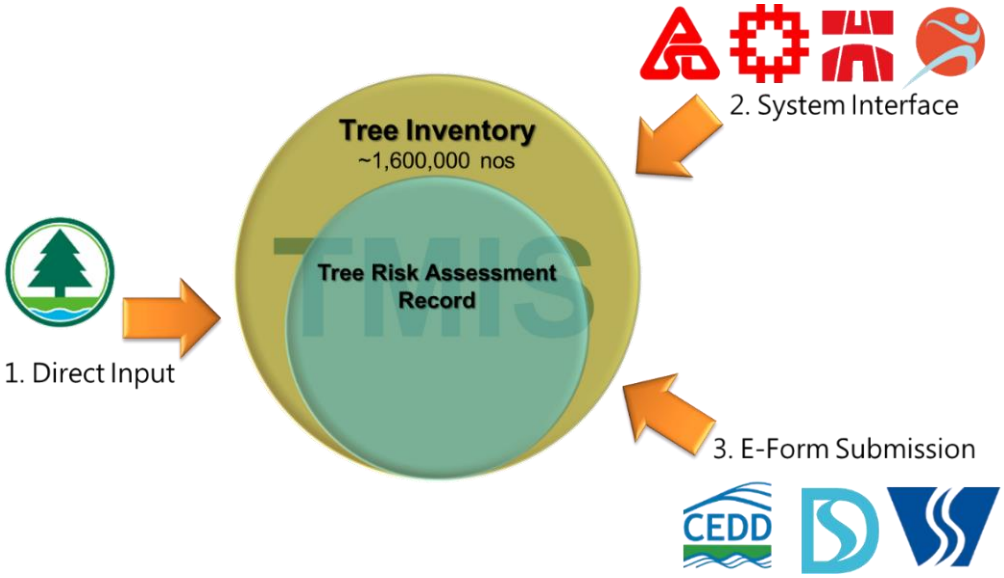


Figure 4.19 – Setup of TMIS

4.10.1.3 In addition, TMIS keeps digitized records of demarcated zones and trees, including spatial boundary and coordinates of individual trees/tree groups, where each tree has their own Masterzone ID, Subzone ID and Tree ID (**Figure 4.20**).

Figure 4.20 – Masterzone and Subzone Demarcation of TMIS

4.10.1.4 Besides, the Department of Land Surveying and Geo-Informatics (LSGI) of PolyU has led a research with support of other academia e.g. HKUST, non-government organizations (e.g. Friends of the Earth) and the B/Ds including DEVB, HyD, LCSD, AFCD to apply smart sensing technology (SST) and GIS for the monitoring of tree stability to enhance timely appropriate mitigation measures for sustaining longer tree lives[43].

4.10.1.5 HKU has also conducted a research on "Tree in high density cities" that focuses on the following aspects[44] (**Figure 4.21**):

- Benefits of street trees
- Tree protections
- Managing high value trees
- Transplanting mature trees

Figure 4.21 – Different Aspects of Trees in HKU Research

[43] https://www.polyu.edu.hk/web/en/media/media_releases/index_id_6551.html
[44] https://www.arch.hku.hk/research_project/trees-in-high-density-cities/

4.10.1.6 Overseas cities such as New York (New York City Street Tree Map)[45](**Figure 4.22**), San Francisco (Urban Forest Map) (**Figure 4.23**) and Niagara[46] (**Figure 4.24**) have GIS-based maps open to public that shows street tree information including Tree ID, species, trunk diameter and ecological benefits as well as other quantifiable benefits including water and energy saving brought by tree growing.

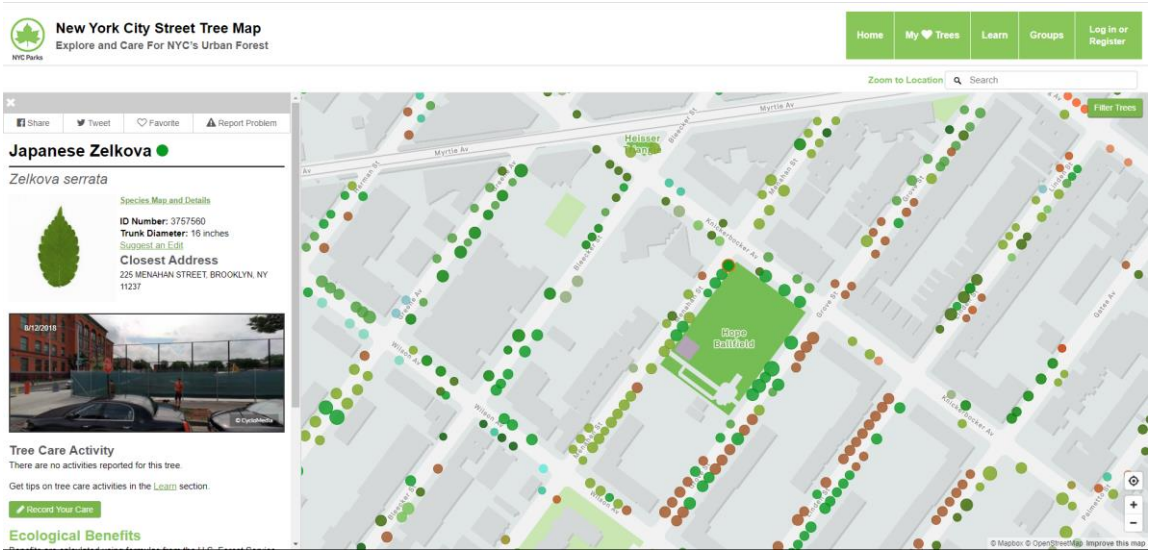


Figure 4.22 – Sample of Tree Management – New York

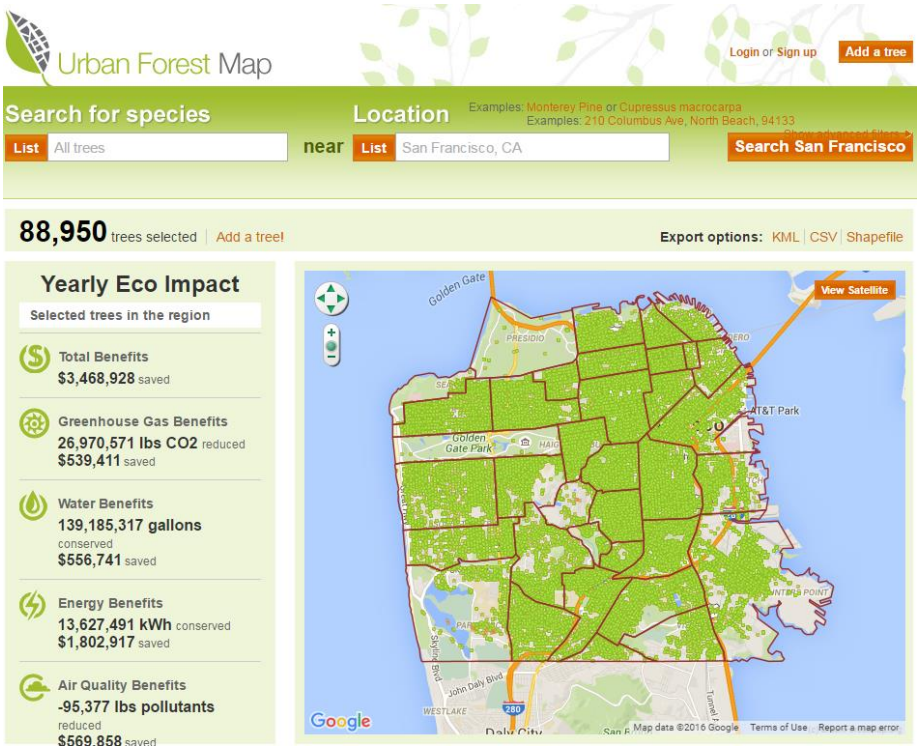


Figure 4.23 – Sample of Tree Management– San Francisco

[45] https://tree-map.nycgovparks.org/#treeinfo-3757560
[46] http://treeocodeniagara.com/

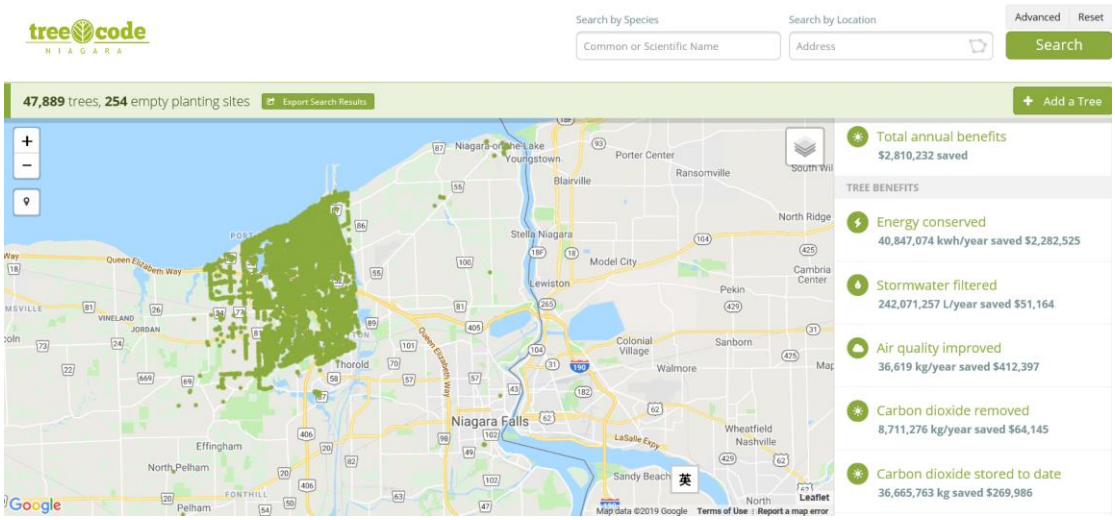


Figure 4.24 – Sample of Tree Management – Niagara

4.10.1.7 As a highly-developed metropolitan city and a city with world-class infrastructure, Hong Kong has long been positioning itself as Asia's World City. In the meantime, Hong Kong is facing a number of changing circumstances and challenges. With a population density of 27,330 persons per square km, Hong Kong is also one of the world's most densely populated cities. A rapidly ageing population, pressing demand for housing, economic activities and community facilities, as well as a growing aspiration for health, well-being and better quality of environment and life, have made Hong Kong to transform to an environmentally friendly, more liveable and sustainable city.

4.10.1.8 Green-related indices offer a mechanism for assessment a city's "Greenness" and the ability to for cities to achieve long-term environmental targets[47]. Hong Kong 2030+: Green and Blue Space Conceptual Framework[48] refers to the index as a combination of parameters focusing on the provision by trees and vegetation. The Asian Green City Index measures environmental performance and commitment to reducing environmental impact, taking into account city operations and resource management.

4.10.2 Purpose

4.10.2.1 The prototype aims to demonstrate the feasibility of providing a common platform for visualizing green-related information, academic research results of green-related indices and adopting relevant methodologies to conduct a variety of green-related analyses with a view to supplementing more information to facilitate making informed decision in the course of built environment planning. It is not intended to come up with any standards and guidelines for green-related analysis. In the future implementation stage, methodologies and results from other studies / researches which are deemed to be valid and conclusive among relevant stakeholders can also be considered to be incorporated in the application, and

[47] Hong Kong's Climate Action Plan 2030+ targets 65% to 70% carbon intensity reduction from the 2005 level, which equates to about 26% to 36% in absolute terms. (https://www.enb.gov.hk/sites/default/files/pdf/ClimateActionPlanEng.pdf)

[48] https://www.hk2030plus.hk/document/Green%20and%20Blue%20Space%20Conceptual%20Framework_Eng.pdf

further investigation and liaison with relevant stakeholders on the details of key functions of the application is still required. Moreover, the prototype is tasked to demonstrate the capability of establishing an ecosystem to facilitate sharing of academic research results and foster co-operation, collaboration and co-creation among B/Ds, academia, professionals, business and different sectors of the community.

4.10.2.2 This ultimate goal of the application is to enable a more comprehensive approach for analyses of urban green infrastructure with the supplementary information on blue infrastructure as follows:

(i) Collect and collate more green/blue data in urban area:

- Inclusion of the green data from existing systems and database: for instance, TMIS under TMO, and Land Utilisation in Hong Kong under PlanD which identifies various vegetation cover from satellite images; and
- Crowd sourcing of green data: to further enrich the green data, results from other studies / researches may be considered to be incorporated in the application subject to further review and feasibility assessment.

(ii) Provide a platform to visualize green related information, which can serve as reference or supplementary materials to facilitate conducting built environment planning. Some examples are shown as below:

- Information or data relating to trees and planting area (e.g. location, size, type, etc.) and impervious landscapes (e.g. pedestrian walkways, bicycle lanes, street parking areas, etc.) can be taken as reference materials in the course of conducting flooding, resilience, walkability and pedestrian planning;
- Some green data namely green roof and façade may have implication to the building structures. Therefore, collection of these information, among others, can be regarded as supplementary information for relevant B/Ds' consideration in delivering the tasks involving building safety checking; and
- Green data can also be correlated with other environmental considerations such as urban heat map, air-quality, etc. to come up with some analysis results/findings on particular aspects such as VD and the anthropogenic heat. These findings may be conducive to the formulation of planning and design requirements.

(iii) Facilitate green analysis in urban area: the platform has the ability to incorporate relevant methodologies, which are deemed to be valid and conclusive among relevant stakeholders, to conduct various green related analyses (e.g. green coverage indicators for various levels from district, site, park to street, tree leaves colour status, blossom status, estimated tree biomass, carbon sequestration, etc.) using existing remote sensing images and tree-related information such as tree species, tree size (e.g. dimensions of tree canopy/crown width), tree health information.

4.10.2.3 This application also aims to provide the datasets and visualization function regarding the urban green infrastructure in Hong Kong, which would form an integral part of city planning and serves as components for sustainable city development.

4.10.3 Benefits

4.10.3.1 Urban green space (UGS) provides numerous benefits to urban residents by acting as urban lungs – absorbing pollutants and releasing oxygen[49,50], providing clean air, water and soil, and balancing the urban natural environment[51]. In a compact city like Hong Kong, the green and blue assets should be leveraged for promoting a liveable high-density city. Therefore, this application is tasked to provide a platform to access various green data, which would assist in developing functional green infrastructures in Hong Kong.

4.10.3.2 With the implementation of this application, it is envisaged that the following benefits can be realized:

- Enable better visualization on analysis results of urban green infrastructure as supplementary information for better decision making for the community, thereby being more resilient to climate change.
- Allow users to have a more comprehensive picture on the greenery of the city, reflected by green index/ratio of each district, which would thus be able to provide preliminary indication or reference on which areas have relatively less green and require planting of more trees.
- Raise the awareness of green impact of the city and foster the conduction of green-related studies.
- Easier understanding on the impacts that greeneries bring to the city. This application demonstrates how users can correlate, analyze and visualize data including landscape resources, landscape values, landscape characters and other environment characteristics.

4.10.3.3 This application would enable the users to easily visualize/access the green-related information, which may be derived from the findings of academic researches/studies from local or overseas universities or professional institutes, to facilitate urban planning and design work. For instance, information on trees and planting area together with impervious landscapes could serve as the reference in the course of conducting flooding and resilience planning.

[49] Hough, M., 1994. City Form and Natural Processes, London: Croom Helm. Haughton, G. and C. Hunter, pp.83-109.

[50] Haughton, G. and Hunter, C., 2004. Sustainable cities. Routledge.

[51] Nijkamp, P. and Baycan-Levent, T., 2004. Urban green space policies: A comparative study on performance and success conditions in European cities.

4.10.4 System Design

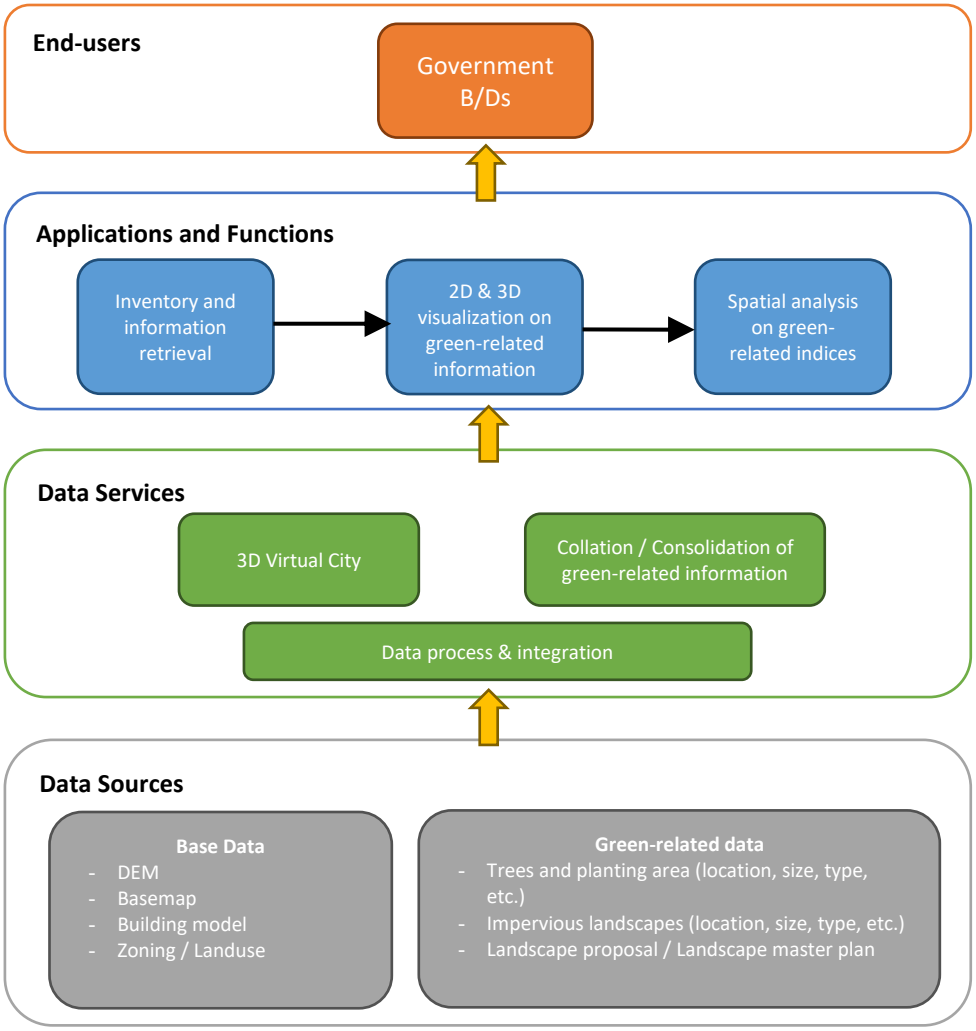


Figure 4.25 – Workflow Diagram of Visualization of Urban Green Management

4.10.4.1 Technical infrastructure:

i. Software: The application runs on web-based GIS, exchanging request with web-server and database for spatial analysis. Maps are created on open source framework using D3.js JavaScript library and Cloudflare security. Image recognition software is used for satellite image pre-processing.

ii. Hardware: Hybrid on-premise and cloud-based storage and Cesium web mapping service are adopted for online hosting GIS application to perform different functions. Implementation of the application would require 8 core 2.6GHz CPU (or above) and 64GB RAM (or above) for smooth operation of functions. Future scale up of the application would need to increase capacity for database, linkage with other built environment data and applications.

4.10.4.2 As illustrated in **Figure 4.25**, the application is undertaken by the following key steps:

i. The prototype demonstrates the feasibility of providing a platform to visualize green-related information and academic research results of green-related

indices. Besides, methodologies suggested by the academic research on conducting green-related analysis are also incorporated in the prototype using existing remote sensing images and tree-related information:

- **Analysis of Green-related Indices** – users can calculate changes to vegetation cover (VC), vegetation density (VD), estimated tree biomass, and green space factor (GSF) for a defined area after the introduction / removal of trees. For adding trees, users are provided with a library of common tree species. The defined area can be user-defined (i.e. users define polygon on map), or based on a predefined selection of parks, OZP or TPU.
- **Shadow Analysis** – simulates shadow movement in a district for a predetermined date and time period with calculations of sunlight and shadow ratio.
- **Visualization of Green-related Indices and Information** – calculations to VC, VD, estimated tree biomass, GSF and anthropogenic heat using remote sensing images and display of green-related information concerning 3D trees and building blocks, green roofs, permeable surface, lawn / shrubs and water.

ii. Using online maps, users can explore existing conditions of greenness in the city. To achieve environmental targets (e.g. carbon reductions), users can simulate planting additional trees on the street or open space. Conversely, users can simulate the removal of trees to view the detrimental effects on green-related indices.

iii. When enhancing walkability of the district, shadow coverage over pedestrian paths shall be taken into consideration as the presence of shadows could improve comfort levels. Changing on shadow coverage as a result from addition / removal of trees can be visualized.

iv. Urban and landscape designers can make use of the application for tree planting and vegetation planter placement design, supporting the planning of greenscape in urban environment.

v. Spatial and statistical analysis of urban greenness is enabled through information on green cover and density, surface covering (e.g. permeable surfaces), biomass and carbon sequestration, and shadow analysis.

4.10.4.3 The application will include the following functions:

i. Analysis of VC and VD;

ii. Biomass estimation for individual trees;

iii. GSF calculation;

iv. Shadow analysis;

v. Spatial / statistical analyses of green related indices after adding / removing trees; and

vi. Annotate, compare, comment, and export the outcomes.

4.10.5 Study Area

4.10.5.1 The prototype focuses on 5 areas in Hong Kong, i.e. Tsim Sha Tsui, Sheung Wan, Central, Admiralty and Wan Chai in **Figure 4.26**. WorldView-3 satellite image is used to demonstrate the capability of functions of this application. **Figure 4.27** shows an overall concept of data processing.

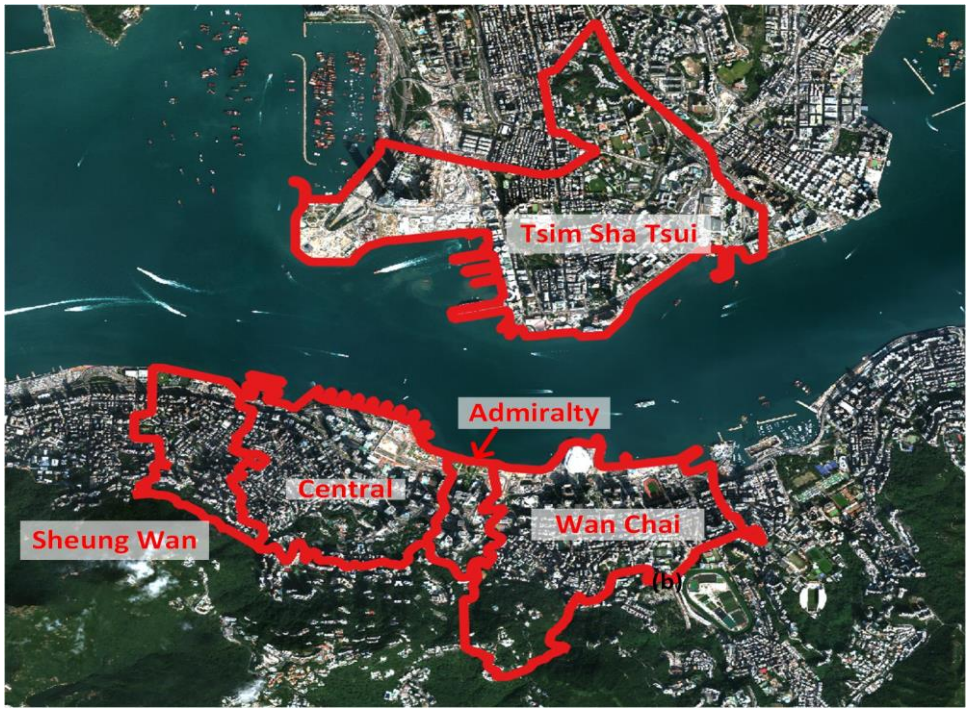


Figure 4.26 – Study Area of the Prototype

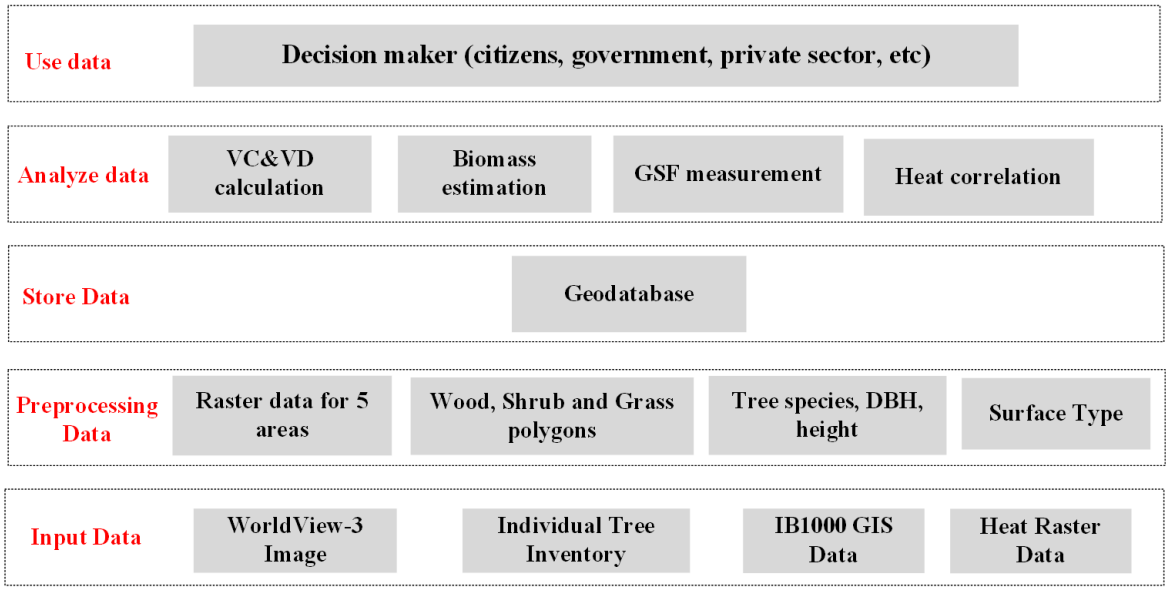


Figure 4.27 – Data Management Process of the Prototype

4.10.5.2 The WorldView-3 multispectral image data is acquired in the year of 2015, with spatial resolution of 1.12 meters. There are eight bands in the multispectral image,

including Coastal, Blue, Green, Yellow, Red, Red Edge, Near-IR1 and Near-IR2. A part of WorldView-3 image that contains the study area is shown in **Figure 4.28**.

Figure 4.28 – WorldView-3 Remote Sensing Image and the Study Area

4.10.5.3 This prototype, which are mainly to provide a platform for sharing the academic results and green-related analysis from stakeholders or professional institutes, can be categorized into four major parts with focus on the visualization and measurement of green space in Hong Kong urban area. The first part embraces the visualization of VC and VD estimation, which would indicate the coverage and density of trees and plants for an area through map interface. The second part is the visualization of the biomass estimation, which is derived based on the assumption and the methodology adopted by the research studies/findings and provides rough indication of potential biomass and carbon sequestration of individual tree depending on its size and species. Thirdly, this prototype would be embedded with a function to visualize the GSF, which is widely adopted in overseas developed countries and academic researches/studies to measure the overall greenness of the study area, taking into account green and blue assets with weighed scoring. Lastly, the prototype has a function of performing shadow analysis to allow users to calculate the shadow ratio of a selected area. Apart from the above, this prototype can also provide a platform to showcase the green-related analysis results involving the correlation between the VC and density with other environmental considerations such as anthropogenic heat, which sheds light on the possible inherent relationship between the vegetated area and microclimate of the area. An overview of the functions is shown in **Figure 4.29**.

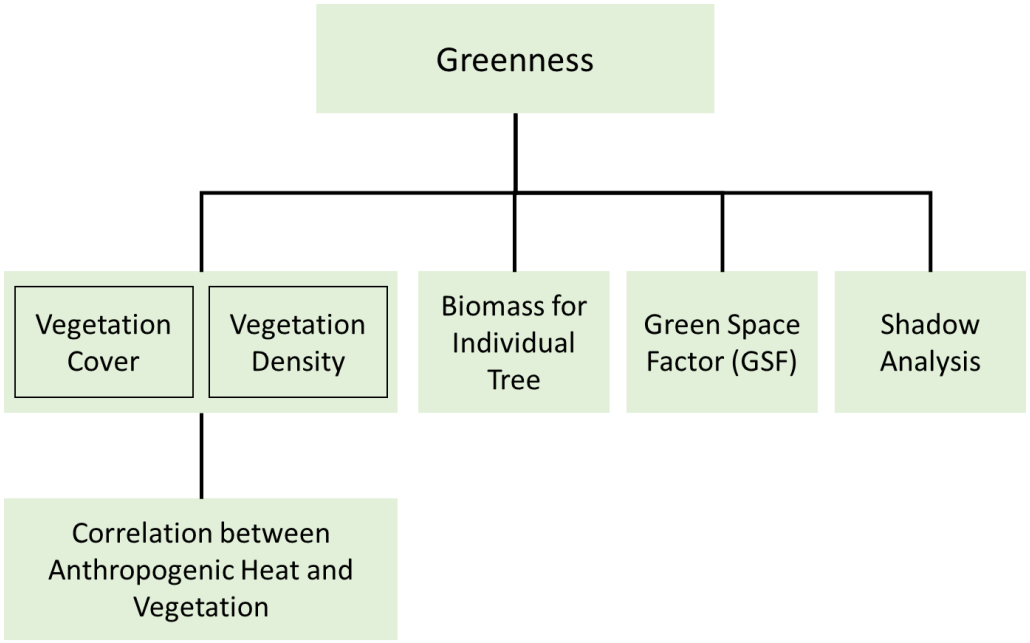


Figure 4.29 – Overview of the prototype

Function	Coverage of this Prototype
Analysis of VC and VD	Various kind of vegetation identified within Study Area
Biomass Estimation	9 tree species selected including Livistona chinensis, Archontophoenix alexandrae, Roystonea regia, Melaleuca cajuputi subsp. Cumingiana, Lagerstroemia speciose, Bauhinia x blakeana, Aleurites moluccana, Ficus microcarpa, Ficus benhamina
Calculation and Visualization of GSF	9 types of surfaces identified within Study Area: Buildings (without green roofs), Buildings (with green roofs), Non-Permeable surface (sealed surface), Semi-permeable surface (e.g. stone with joints), Semi-permeable surface (e.g. gravel), Tree fully grown ≥ 6 m, Shrub (< 6 m), Lawn, and Open water surface
Shadow Analysis	Buildings or trees within Study Area

Table 4.17 – Coverage Area of the Prototype

4.10.6 Functions

4.10.6.1 The functions delivered and tested in the prototype development process and to be included or requiring further development in the implementation stage are summarised in **Table 4.18**.

	Key Functions		Prototype Development	Implementation Stage
i.	Visualization of VC and VD analysis	a. Visualize VC and VD results in map view	- Delivered and tested - Incorporate the result of modelling VC and VD for the study area i.e. Tsim Sha Tsui, Sheung Wan, Central, Admiralty and Wan Chai	- Extent the coverage of VC and VD to the whole territory - To enhance the modelling results of VC and VD, collect ground samples across whole territory, and obtain more information e.g. green roof or sky garden - Increase spatial and temporal resolution of VC and VD analysis
		b. Visualize the result of correlation analysis between urban heat and vegetation	- Delivered and tested - Visualize the urban heat map	- Incorporate the correlation function in the application
ii.	Visualization of Biomass estimation for individual trees	a. Visualize biomass estimation results in map view	- Delivered and tested - Incorporate the result of biomass estimation of 9 selected tree species, with a general calculation model for other tree species - Available tree data collected for the purpose of Tree Risk Assessment for trees located in Catergory 1 zone recorded in TMIS, and visualize pre-calculated biomass estimation for the study area	- Incorporate biomass estimation equations for more tree species for a more accurate calculation - Calculate the biomass using remote sensing technology for the whole territory

	Key Functions		Prototype Development	Implementation Stage
iii.	Visualization of GSF	a. Visualize GSF in map view	- Delivered and tested - Incorporate the result of GSF designed for Hong Kong situation	- Allow adjusting GSF scoring scheme - Include more factors in GSF calculation - Increase resolution of GSF calculation subject to data availability
iv.	Shadow analysis	a. Visualize shadow profile of a selected area throughout a selected timeframe	- Delivered and tested	- To be included
		b. Calculate sunlight ratio of a selected area	- Delivered and tested	- To be included
v.	Spatial / statistical analyses of green-related indices after adding / removing trees	a. Visualize trees in map view in 3D environment	- Delivered and tested - Available tree data collected for the purpose of Tree Risk Assessment for trees located in Category 1 zone recorded in TMIS in the study area	- Include more individual tree information for entire Hong Kong subject to data availability
		b. Add/remove trees in any location	- Delivered and tested - Allowing selection of 9 tree species and 1 general tree type	- Include more tree species

	Key Functions		Prototype Development	Implementation Stage
		c. Perform spatial / statistical analyses of green related indices based on user-defined area and show the changes	- Delivered and tested	- To be included

Table 4.18 – Functions of Application in Prototype and Implementation Stages

4.10.7 Data Requirement

4.10.7.1 Interfacing datasets used in this prototype, as well as suggested additional datasets subject to further review for implementation are listed in **Table 4.19**. In future implementation stage, further liaison and agreement with respective B/Ds on the use of the datasets in the application would be required.

B/Ds / Other Parties	Data / Dataset for this Application	Included in Prototype Stage	Included in Implementation Stage
LandsD	Digital Topographic Map iB1000, iB5000, iB10000, iB20000	Yes	Yes
	Digital Orthophoto DOP5000	Yes	Yes
	3D Spatial Data (i.e. Buildings, Roads, Terrain, etc.)	Yes	Yes
CEDD	LiDAR Data (2011)	Yes	Yes
PlanD	OZP	Yes	Yes
	WorldView-3 image	Yes	Yes
	3D Photorealistic Mesh Model	Yes	Yes
TMO	Available tree data collected for the purpose of Tree Risk Assessment for trees located in Category 1 zone	Yes	Yes
	Tree data (information other than individual tree data in Category 1 zone) e.g. data in Category 2 and Category 3 zones	No	Yes
PolyU	Anthropogenic Heat	Yes	Yes
	Estimated tree biomass	Yes	Yes
	GSF	Yes	Yes
	VC	Yes	Yes
	VD	Yes	Yes
Relevant Parties	Vertical greening information	No	Yes

B/Ds / Other Parties	Data / Dataset for this Application	Included in Prototype Stage	Included in Implementation Stage
Relevant Parties	Other satellite images (e.g. SPOT)	No	Yes

Table 4.19 – Data Requirement of this Application

4.10.8 Scale up of the Application

4.10.8.1 This application should be considered to collate or integrate the state-of-the arts technologies and applications for supporting "smart, green and resilient" city, e.g. strategically. It may not only to serve as data hub for collecting data/information, the ultimate target should be to provide tools for quantifying various aspects of greenness in a city.

4.10.8.2 Greenery in Category 2 and Category 3 zones (for the purpose of Tree Risk Assessment) can be further developed in the long run to enrich the coverage of the application.

4.10.8.3 As technologies are becoming more and more advanced, it is envisioned that the updating of different data of this application can be automated, providing a more dynamic and real-time visualization and analysis of green in the city.

4.10.8.4 The application can be further developed to monitor through remote sensing to check actual green coverage in operation stage at various developments.

4.10.8.5 With the functionality of visualizing the green cover area and undertaking green-related analyses, it is anticipated that the users from different B/Ds can easily access to the green-related information to help facilitate daily operation and decision-making process. Examples of correlated applications are as follows:

- To analyse the possible impact of UGSs on reducing urban heat, offsetting greenhouse gas emissions, and attenuating storm water
- To facilitate undertake various planning/analyses tasks e.g. pedestrian planning
- To provide reference materials for relevant B/Ds, namely identification of the location and quantity of green roof to facilitate checking against the loading of the roof structural of corresponding building

4.10.8.6 In the future, it is also recommended that research for the entire Hong Kong during different seasons should be conducted in order to capture the changes of greenness in the territory. In addition, to enhance robustness of the application, more data regarding vegetation and biomass should be collected in future work subject to sufficient manpower and cost.

4.11 Built Environment Information Dashboard

4.11.1 Background

4.11.1.1 The PSI Portal (data.gov.hk) has stored a wide range of city data, from city management, traffic flow to climate forecast. These datasets are open to public freely that can be used for academic research, private studies and the development of commercial applications. Data are available for download and API builders are provided for data extraction.

4.11.1.2 There is a collection of web and mobile applications developed by both government and community using datasets in the PSI Portal. These applications include property search by real estate agencies, journey search for public transport commuters and car drivers, and news reader, etc. OGCIO is developing a city dashboard function on the PSI Portal for the public to view city data, such as traffic, transport, environment and weather, which is expected to be rolled out in the fourth quarter of 2019.

4.11.1.3 Apart from the PSI Portal, there is also another platform, MyGovHK (**Figure 4.30**), which is a personalized interface developed on the GovHK portal (https://www.gov.hk) to meet citizens' needs, offers quicker and more convenient access to personalized online services and information. Citizens can create their own MyGovHK account for free and organise their own lists of frequently used online services and information inside the personalised interface.

Figure 4.30 – MyGovHK Webpage

4.11.1.4 The GeoInfo Map (**Figure 4.31**) providing accurate maps with geospatial information developed by LandsD to serve the general public, was revamped and launched in December 2018. Other than the dedication of facilitating the searching and understanding of geographical locations, the built and natural environments, and public facilities in Hong Kong, the latest map is revamped with enhanced map functions and location search engine, which enables searching for real-time information including weather, traffic, air and beach water quality. Geo-hashtags feature is newly introduced to explore and obtain location information.

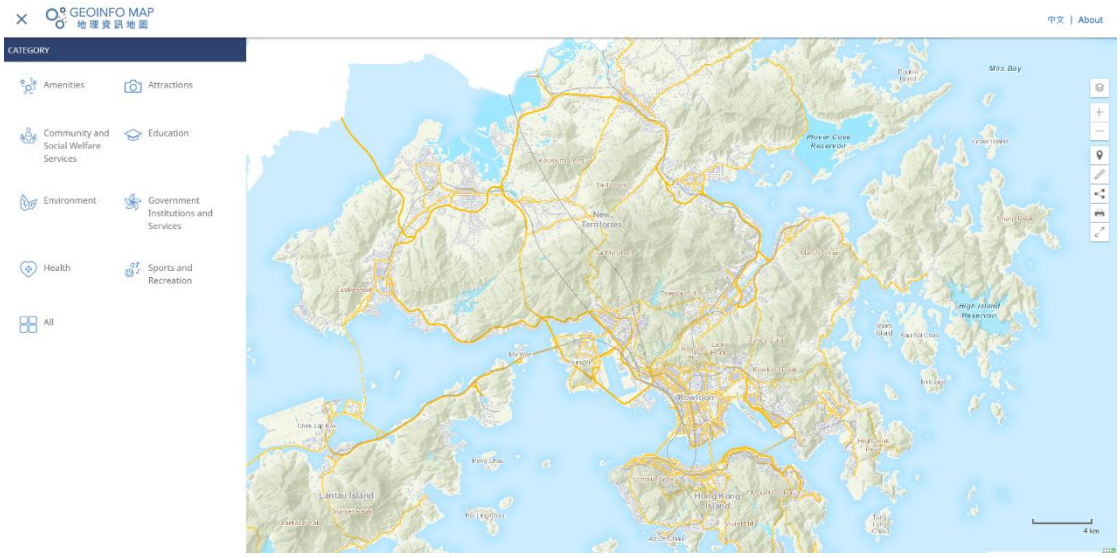


Figure 4.31 – Geoinfo Map Website

4.11.1.5 In addition, LandsD also launched the new Hong Kong GeoData Store (**Figure 4.32**) in December 2018, which is an alpha version of the CSDI Portal and a public platform for exploring and downloading spatial data provided by various government departments, facilitating the discovery and dissemination of various types of spatially-enabled PSI in various categories (e.g. culture, education, environment, government, health, social welfare, sports, technology, etc.) in open format and API services for free re-use for both commercial and non-commercial purposes. A user-friendly map interface is provided for users to easily browse various geospatial datasets. 79 types of public facility geospatial data sourced from the GeoInfo Map into open and machine-readable formats of GeoJSON, GML, KML and CSV together with an API to facilitate free download and use by the public. The portal is also equipped with other useful API services, including the Location Search API, Search Nearby API and Identity API to support innovative map applications by developers, saving time and cost when developing applications.

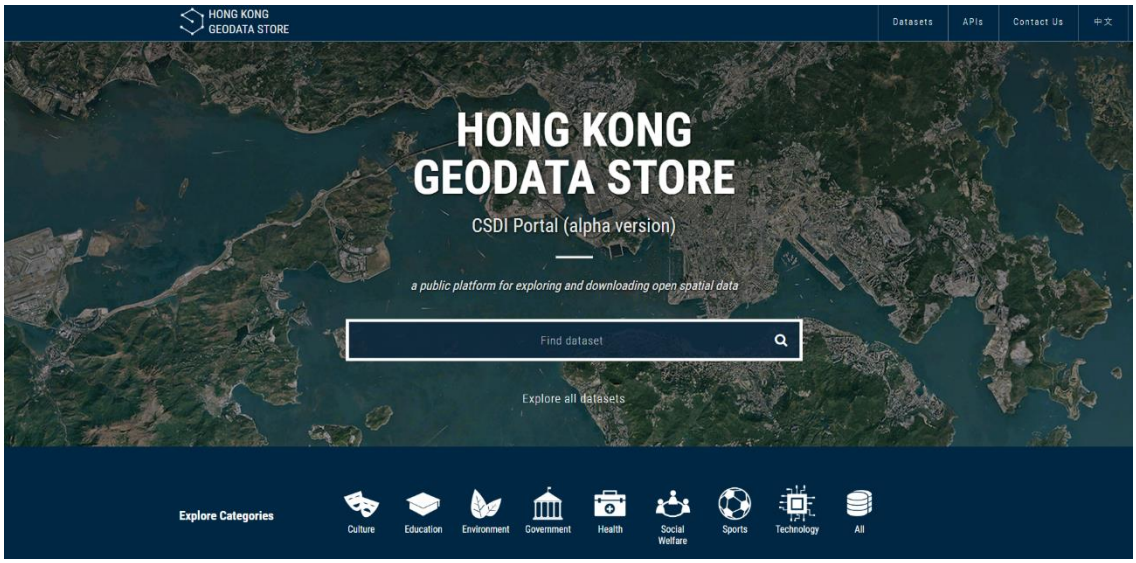


Figure 4.32 – GeoData Store Website

4.11.1.6 Public services in private sector such as utility companies, MTR and bus companies also develop their own applications with functions including billing records and bus arrival time, etc.

4.11.1.7 Overseas cities such as London and Glasgow have developed similar city information dashboards (**Figure 4.33**) for citizens to visualize interested information. For instance, "CityDashboard" (http://citydashboard.org/london/) in London aggregates and displays simple data, such as cycle rental and tube line status on a dashboard and a map.

Figure 4.33 – Sample of Dashboard UI of London and Glasgow

4.11.1.8 There are some other similar applications developed in London:

- Datashine

  A data mapping platform developed by "Mapping London" at University College London to show mainly the Census datasets for London (and some other major cities in the UK) (**Figure 4.34**), with different Census metrics to demonstrate topics such as housing structure, occupation, and method of travel, etc.

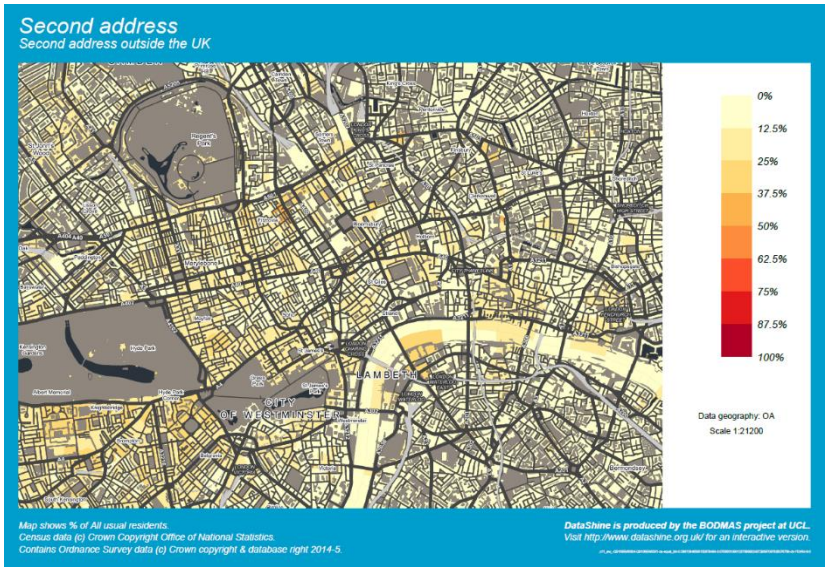


Figure 4.34 – Sample of Datashine

- Maps by the Mayor of London

  The London Assembly (Mayor of London) has also released maps with different themes, including but not limited to:

  - Regeneration Projects: https://www.london.gov.uk/what-we-do/regeneration/projects-map
  - Street Trees: https://maps.london.gov.uk/trees/
  - Planning Permission: https://maps.london.gov.uk/ldd/
  - London Land Commission Register: https://maps.london.gov.uk/LLC/
  - Zero Carbon Tool: https://maps.london.gov.uk/zerocarbon/
  - London Rents: https://www.london.gov.uk/what-we-do/housing-and-land/renting/london-rents-map
  - Map of London's Music Spaces: https://maps.london.gov.uk/music-facilities/
  - London Tree Canopy Cover: https://maps.london.gov.uk/canopy-cover/

- City of London – Interactive Mapping

  The City of London has also developed an interactive map to show city information (e.g. city toilets, post offices, hotels, taxi ranks, recycling bins, protected trees, areas related to local plan policies, etc.) with simple icons/interface

4.11.2 Purpose

4.11.2.1 Acknowledging the current available websites such as the GeoInfo Map, Hong Kong GeoData Store and MyGovHK, this platform will serve as the landing page of BEAP that displays key information relating to built environment and planning and development information captured from the applications of BEAP, with the following key objectives:

- Provide a landing portal to gain access to all the BEAP applications;
- Facilitate better understanding of different kinds of data from BEAP applications by the general public and advance their awareness and interpretation of official information related to the built-environment from different B/Ds;
- Facilitate users to further perform interactive analysis on the map interface, in which they are able to map out and generate their own visualizations and analysis from different datasets to garner insights; and
- Improve the user-experience by allowing users to personalise and choose the information to be visualized.

4.11.3 Benefits

4.11.3.1 With the implementation of this application, it is envisaged that the following benefits can be realized:

- Provide a single platform to facilitate users to easily personalize their built environment and socio-economic information and visualize planning and development information from selected BEAP applications in a consolidated and spatially enabled format.
- Allow local familiarity of the city and expedite the city's positive and forward-thinking attitude towards integrating various built environment related as a result of synergy of data and functions.
- B/D users can spatially visualizing various information and conducting analysis in facilitating the policymaking and other decision-making process

4.11.4 System Design

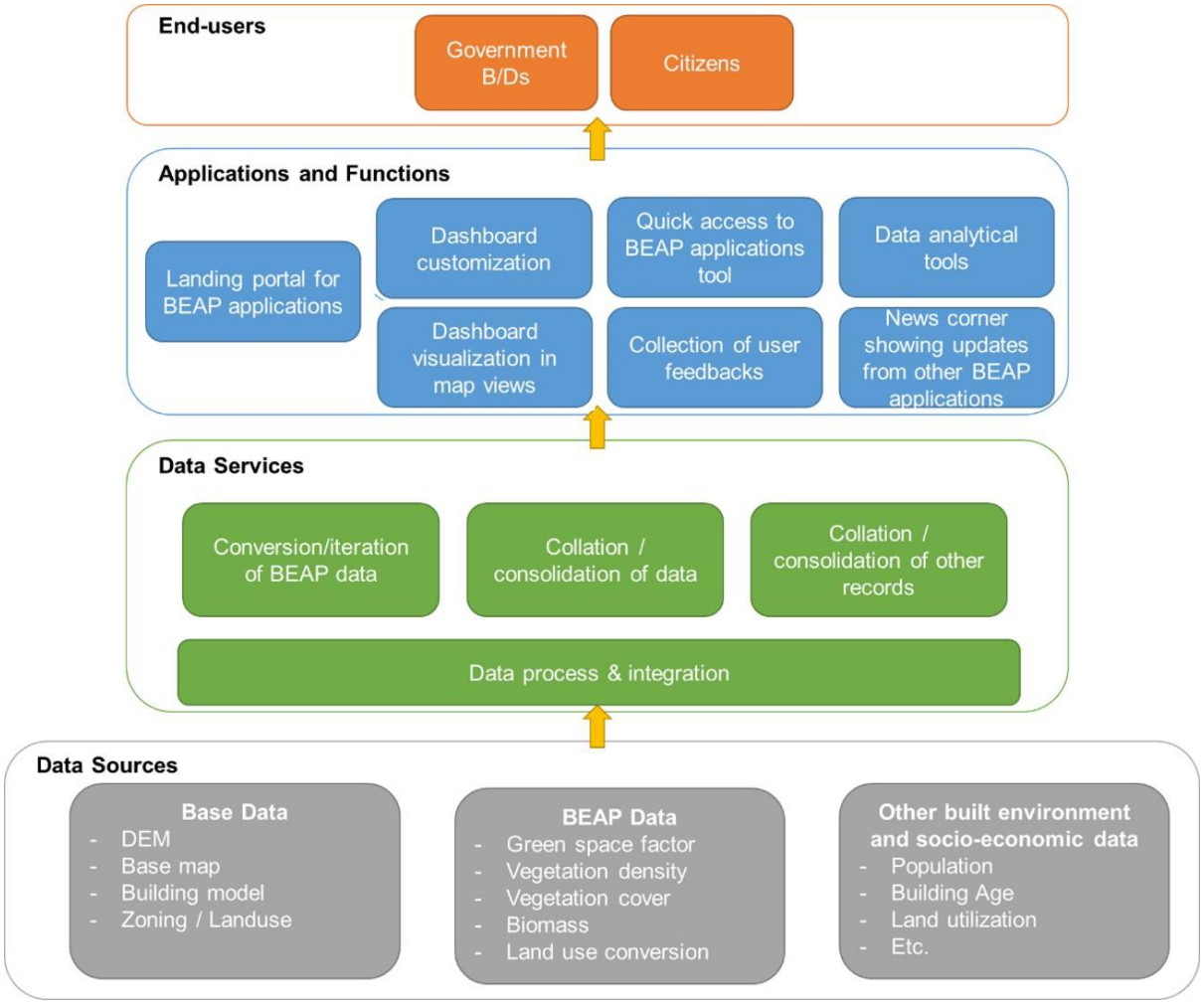


Figure 4.35 – Workflow Diagram of Built Environment Information Dashboard

4.11.4.1 Technical infrastructure:

- Software: The prototype is developed as a web-based application based on proprietary software. During the implementation stage, full web-based development can be explored.
- Hardware: The prototype is developed on a private cloud environment with a setting of 8 core 2.6GHz CPU (or above) and 64GB RAM (or above). This setting is also applicable for future implementation of the application.

4.11.4.2 The application will capture selected key information from the applications of the BEAP, such as green ratios and data from the walkability analysis. Other key information and data such as built environment and socio-economic data will also be incorporated to form a fundamental back-end database. These data will be converted and consolidated to be visualized and analysed on a map viewing interface interactively, which would be undertaken by the following steps (**Figure 4.35**):

i. Users will be able to gain access to the BEAP applications via this landing portal, including the dashboard where they can customize and personalize the information they concern to be displayed. The application will retrieve

information from the back-end database to visualize in map views for interactive analysis upon the request of the users. Analyses could also be conducted by comparing different datasets on the dashboard.

ii. Tools developed from other BEAP applications are also included on the dashboard as "quick tools" for direct access to some functions of the applications.

iii. Feedbacks from users can also be collected onto the back-end management of the application so that functions and data availability/comprehensiveness of the application can be constantly updated and improved. Updates from other BEAP applications, such as new uploads of site photos in the Landuse Monitoring and Analytics, shall be shown in the "What's new" windows to alert the users.

4.11.5 Study Area

4.11.5.1 The prototype included socio-economic information to be displayed on map with selected criteria such as age group and year of projection. Socio-economic data are census information extracted from By-census result by C&SD, the 2014-based TPEDM and the WGPD for 2026 complied by PlanD.

4.11.5.2 Built environment information, such as building age and residential types, was also incorporated for demonstration. Correlation analyses were demonstrated by comparing various datasets, such as a comparison between ages of population and building age to illustrate the double aging condition.

4.11.5.3 Information from Visualization and Analysis of Urban Green Infrastructure prototype was also included in the prototype, including GSF, VC and biomass to demonstrate the visualization of information from other BEAP applications.

4.11.5.4 Selected information was used to provide KPIs to demonstrate the customization function of the dashboard.

4.11.5.5 The function of Landuse Recognition from Landuse Monitoring and Analytics prototype is included as a quick tool on the dashboard for demonstration. Besides taking Landuse Monitoring and Analytics prototype as an example to demonstrate real-time connection with other prototypes, a notification will be shown in "What's new" window to inform the user of the newly uploaded site photos.

4.11.6 Functions

4.11.6.1 The functions delivered and tested in the prototype development process and to be included or requiring further development in the implementation stage are summarised in **Table 4.20**.

	Key Functions		Prototype Stage	Implementation Stage
i.	Landing portal	a. Landing page for BEAP and Built Environment Applications	- Delivered and tested	- To be included

	Key Functions		Prototype Stage	Implementation Stage
ii.	Spatial visualization of information	a. Allow selecting information based on preference	- Delivered and tested	- Include more built environment related information and data from other BEAP applications
		b. Interactive analysis among different dashboards	- Delivered and tested - Visualize data with timeline bar and use pre-selected data set for correlation analysis	- Allow selecting different data to perform correlation analysis
iii.	User customization	a. Customize the layout of map views and KPI	- Delivered and tested - Allow user to select and apply different legend - Allow user to display pre-selected KPI	- Allow customizing the display layout and windows - Include user account for individual user to save personal profile and preference - Allow defining KPI to be displayed
v.	User feedback	a. Allow submitting feedback and comments on functions and data availability	- Delivered and tested - Provide interface to submit feedback	- Develop backend comment analysis tool to review and classify user comment
vi.	Interaction between dashboard and other applications	a. "Quick Tool" to access functions of and data from other BEAP applications	- Delivered and tested - Allow interaction with Landuse Monitoring and Analytics prototype (A hyperlink to "Landuse Recognition by AI" under Landuse Monitoring and Analytics prototype is provided)	- Extend interaction with other applications and enable updates of newsfeeds on different datasets - The "Quick Tool" allows direct access to the functions and data of other applications.

	Key Functions		Prototype Stage	Implementation Stage
		b. News pop-up window	- Delivered and tested	Allow regular updates from other applications

Table 4.20 – Functions of Application in Prototype and Implementation Stages

4.11.7 Data Requirement

4.11.7.1 Interfacing datasets used in this prototype, as well as suggested and additional datasets subject to further review for implementation are listed in **Table 4.21**. In future implementation stage, further liaison and agreement with respective B/Ds on the use of the datasets in the application would be required.

B/Ds / Other Parties	Data / Dataset for this Application	Included in Prototype Stage	Included in Implementation Stage
LandsD	Digital Topographic Map iB1000, iB5000, iB10000, iB20000	Yes	Yes
	Digital Orthophoto DOP5000	Yes	Yes
PlanD	WGPD	Yes	Yes
	TPEDM (2014-based)	Yes	Yes
	Land Utilization Maps (2014, 2015, 2016 and 2017)	Yes	Yes
	Age of buildings	Yes	Yes
	Existing Open Space	Yes	Yes
	Residential Landuse	Yes	Yes
	TPU	Yes	Yes
CEDD	LiDAR Data (2011)	Yes	Yes
C&SD	Population By-census (2006, 2011 and 2016)	Yes	Yes
HAD	District Boundary	Yes	Yes
AFCD	Boundary of Country Park	Yes	Yes
EPD	Noise Contour	No	Yes
	Air Quality Contour	No	Yes
TD	Annual Traffic Census	No	Yes

Table 4.21 – Data Requirement of this Application

4.11.8 Scale up of the Application

4.11.8.1 Apart from B/Ds, public and private organizations can be encouraged to participate in the development of this application, and to provide necessary data for the enhancement of the platform.

4.11.8.2 The interface of this application can be further expanded to mobile devices such as smart phones and tablets.

4.11.8.3 When other applications from BEAP become more mature, more different types of data can be extracted and updated on the dashboard for users frequently. Navigation function can also be installed so that the users can obtain the built environment related data feeds of the areas according to their positions.

4.12 Workflow Management Platform

4.12.1 Background

4.12.1.1 Currently, the Study Briefs and related tender documents of some consultancy studies needed to be circulated among relevant B/Ds for comments from different subject officers from different professional disciplines before the process of invitation of tender. The circulation process currently is based on email correspondences and it is time-consuming.

4.12.1.2 While reviewing the draft Study Briefs and related document, there is a need to understand the background of the proposed study. As such, retrieving archived information relating to the subject matter is important. Currently, it is a very time-consuming step to retrieve the previous information as most of the information is stored with paper based.

4.12.1.3 There are many studies commenced every year and most of the Study Briefs needed to be circulated for departmental comments, streamlining the circulation process among departments can definitely improve the efficiency.

4.12.2 Purpose

4.12.2.1 This application aims to provide a collaborative platform for B/Ds to:

- Streamline circulation process among different B/Ds;
- Establish a workflow management collaboration environment to facilitate different B/Ds to comment on the Study Briefs and tender documents as well as retrieve relevant document or past records for reference; and
- Establish a repository for previous relevant studies.

4.12.3 Benefits

4.12.3.1 With the implementation of this application, it is envisaged that the following benefits can be realized:

- Streamline circulation process among B/Ds and facilitate B/Ds to tender their comments via the common platform.
- Increase efficiency on documents and comments retrieval from previous and related studies/projects.

4.12.4 System Design

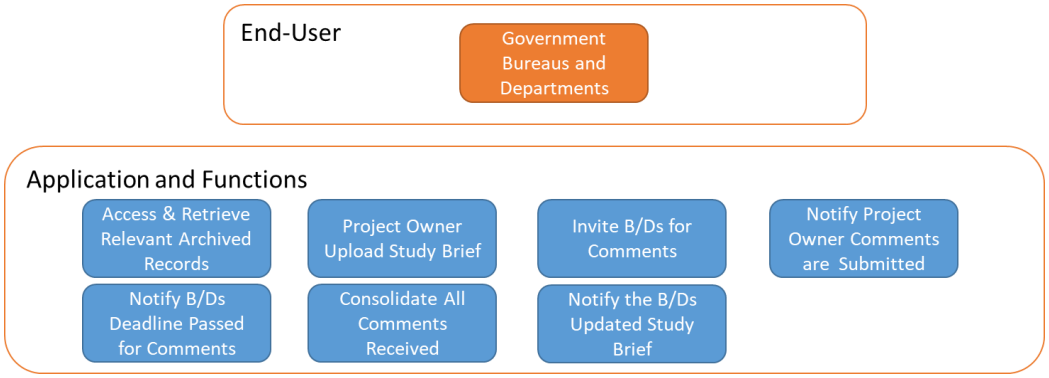


Figure 4.36 – Diagram of Workflow Management Prototype

4.12.4.1 Technical infrastructure:

i. Software: The prototype is developed based on a proprietary software which provides web interface for the required functions. During the implementation stage, it is recommended to assess whether proprietary or open source software is the most suitable technology for the application development.

ii. Hardware: The prototype is developed on a private cloud environment with a setting of 8 core 2.6GHz CPU (or above) and 64GB RAM (or above). This setting is also applicable for future implementation of the application.

4.12.4.2 The application will enable the Study Briefs and tender document to be consolidated under single collaborative environment for B/Ds to search, review, and provide comments.

4.12.5 Study Area

4.12.5.1 The prototype is developed by using samples of the Study Briefs and in conjunction with the workflow routing demonstration for circulating the documents among B/Ds.

4.12.6 Functions

4.12.6.1 The functions delivered and tested in the prototype development process and to be included or requiring further development in the implementation stage are summarised in **Table 4.22**:

	Key Functions		Prototype Stage	Implementation Stage
i	Retrieve archived records	a. Define different types of Study Briefs / tender documents	- Delivered and tested.	- To be included
		b. Search the archived Study Briefs	- Delivered and tested.	- To be included

	Key Functions		Prototype Stage	Implementation Stage
ii	Upload Study Briefs / Tender Documents	a. Upload Study Briefs / Tender Documents and other relevant documents	- Delivered and tested.	- Incorporate all relevant geo-referenced documents that required to be cross-referenced and shared among multiple B/Ds
iii	Invite B/Ds for comments	a. Notify B/Ds regarding Study Briefs	- Delivered and tested. - Specify which part of circulated document B/Ds should pay particular attention / tender comments to	- To be included
		b. Prepare template for B/Ds to provide comments	- Delivered and tested.	- To be included
iv	Notify users upon receipt of comments	a. Notify project proponent when comments have been received	- Delivered and tested. - Comments can be consolidated	- To be included
		b. Set the recipients of the comments	- Delivered and tested.	- To be included
v	Notify users of outstanding tasks	a. Notify users if deadline has passed and comments are not yet provided	- Delivered and tested.	- To be included
vi	Notify B/Ds of updated version of Study Briefs / tender document	a. Send notification to B/Ds	- Delivered and tested.	To be included

Table 4.22 – Functions of Application in Prototype and Implementation Stages

4.12.7 Data Requirement

4.12.7.1 Interfacing datasets used in this prototype, as well as suggested and additional datasets subject to further review for implementation are listed in **Table 4.23**. In future implementation stage, further liaison and agreement with respective B/Ds on the use of the datasets in the application would be required.

B/Ds / Other Parties	Data / Dataset for this Application	Included in Prototype Stage	Included in Implementation Stage
LandsD	Digital Topographic Map iB1000, iB5000, iB10000, iB20000	Yes	Yes
	Digital Orthophoto DOP5000	Yes	Yes
	LOD2 Building Models	Yes	Yes
	3D Spatial Data (i.e. Buildings, Roads, Terrain, etc.)	Yes	Yes
PlanD	Sample Study Briefs in PDF	Yes	Yes
	3D Photorealistic Mesh Model	Yes	Yes
CEDD	LiDAR Data (2011)	Yes	Yes
HyD	Excavation plans and extents from XPMS	Yes (One excavation case in Tsim Sha Tsui)	Yes
B/Ds	System Integration of Archived Study Briefs / tender documents	No	Yes

Table 4.23 – Data Requirement of this Application

4.12.8 Scale up of the Application

4.12.8.1 In the future, this application can be integrated with current or legacy systems to enrich the database. All the future Study Briefs / tender documents should also be supplemented with spatial dimension. When the application becomes mature, it can also be applied to other daily operations which require circulation among B/Ds, e.g. S.16 planning application.

4.13 Lessons Learned during Prototype Development

4.13.1.1 The above sections have provided brief elaboration on the scope and functions of each prototype application. The prototype development process has involved discussion with stakeholders and B/Ds, consolidation of user requirements, collation of different datasets, testing of software and hardware, etc. The key lessons learnt collectively from these 10 prototypes developments are described below:

4.13.1.2 The lessons learnt from the prototype development, which can be divided into two types: negative (e.g. constraints) and positive (e.g. departmental support, potential collaboration with various parties, valuable findings, etc.), can correspond to the BEAP conceptual model and its four building blocks. Details for negative and positive lessons learnt are summarised in **Table 4.24** and **Table 4.25** respectively:

Building Block	Negative Lessons Learned
Applications Development	• Key core built-in functions of proprietary software enable an accelerated and cost-effective development of some functions of applications. Without the use of proprietary software, some applications may need a long time and larger cost to develop. • Proprietary software provides an advantage in functionality development, but the user interface can be too complex for non-experienced user. A simple and user-friendly user interface customized specifically for each application can enhance the overall user experience.
Actionable Data for Applications Development	• Some data are not yet in digital format or found without mutually agreed standard, e.g. the data relating to the underground utilities. The missing of data standard is a hurdle for forming an accurate 3D model for the underground for visualization and analysis purposes. It also involves extensive data pre-processing work to create usable action data. • Some data that are of spatial importance were only available in two-dimensional and/or non-machine-readable format, e.g. the building pile information, underground utilities pipeline and underground tunnels, etc. It is a time-consuming process to convert and transform these data into actionable data. • Some data sources obtained for the prototype development are in various format and requires reformatting and cleaning, which could result in the data loss.
Technical Infrastructure	• The prototypes developed and hosted in consultants' web server would only be appropriate for short term demonstration purpose. A full assessment should be performed to assess software and hardware specification for full scale development of the applications.
Business Architecture and Operating Model	• Different software have different license model and the cost for different level of user are subject to change. For example, users with different access right, including the administration right, editing right and viewing right, should have different costs. License required for each application should be evaluated individually according to their application type, user level and number of licenses required

Table 4.24 – Negative Lessons Learned during Prototype Development

Building Block	Positive Lessons Learnt
Applications Development	• B/Ds require functions that are adapted to the local guidelines in order to maximize the use of the application and enhance the user experience. Application developers need to have a good

Building Block	Positive Lessons Learnt
	understanding of these guidelines and their practical application to facilitate the application development. • Application development requires in-depth understanding of the functions to be developed to know its capabilities and limitations. The development team must work closely with subject experts to acquire comprehensive knowledge and end user requirements to facilitate a more efficient development of functions.
Actionable Data for Applications Development	• The data to be consumed by the BEAP will come from a single source (i.e. CSDI). • Within the current prototype development, good data availability was observed. B/Ds were able to provide most of the data required to construct the Hong Kong virtual twin and make it possible to access to the required regulation and guidelines during the development of the prototype. • With the wider use of real-time sensors, the accuracy of some data can be improved. For example, pedestrian network can include the real routes and flow of the pedestrians from IoT feeds.
Technical Infrastructure	• Prototypes with complex 3D operation and real-time analysis requires demanding hardware configuration. High performance hardware and network are recommended for long term operation use in implementation stage.
Business Architecture and Operating Model	• Security: The prototypes developed on an environment, which is natively secured, only allow access to authorized users. In implementation stage, different security layers should be established to enable differentiated access control at data and actions level for each user. • Governance: It is common to have minor adjustments on the functionality during application development stage. Regular review and meeting with B/Ds are essential to ensure the function requirements and application content are aligned. • Governance of the application will be transferred to B/Ds. • For each individual application, full-time operator(s) would be required for the long-term operation of the application, including maintenance, access rights and account credentials control.

Table 4.25 – Positive Lessons Learnt during Prototype Development

4.14 Potential Linkages among BEAP Applications

4.14.1.1 One of the key objectives of the BEAP is to form an eco-system for collaboration between applications developed by various parties. In other words, each application should not be in silo but potentially forming a mutually symbiotic relationship with each other so that the outputs of each application can be used by others.

4.14.1.2 The possible linkages and interdependency among the 10 applications under BEAP are summarized in **Table 4.26**. Some potential uses of the outputs from the 10 applications to other applications are also suggested. All linkages and data interface between applications should be further reviewed and refined in the implementation stage, subject to the detailed design of the platform and each application.

		Input to the Applications										
	Applications	**Landuse Monitoring and Analytics**	**Site Search**	**Scenario Generation for Planning and Development**	**GIC Facilities and Open Space Analysis**	**Connectivity Analysis**	**Visualization and Analysis of Underground Space and Utilities**	**Compliance Checking of Building Plans**	**Visualization and Analysis of Urban Green Infrastructure**	**Built Environment Information Dashboard**	**Workflow Management Platform**	**Other Application Examples**
Output from the Applications	**Landuse Monitoring and Analytics**					Classified landuses e.g. retail shops based on AI technologies and street images captured by mobile device or vehicles to enhance the walkability analysis			Subject to availability of data sources, trees or vegetation identified based on satellite images, AI technologies and tree images captured by UAV can facilitate formulation of green-related indices			Landuse changes detected can be used for screening or monitoring purposes such as brownfield, illegal dumping, tree compensation, unauthorized building works, etc.
	Site Search				Potential sites for GIC facilities and open space identified can be used for further analysis							
	Scenario Generation for Planning and Development									Enable visualization of planning schemes with different parameters in 3D views	Provide information of preliminary options generated for preparation of Study Brief and related documents of various development projects	Provide a common platform for sharing baseline results of various technical assessments of each project
	GIC Facilities and Open Space Analysis		Analytical functions such as service area analysis to provide a comprehensive assessment of the opportunities and constraints of the potential sites	Forecast of the requirements of GIC facilities and open spaces in different planning options		Incorporate the latest GIC facilities and open space dataset into the connectivity analysis		Incorporate the latest GIC facilities and open spaces dataset for related compliance checking	Incorporate the latest GIC facilities and open space dataset to understand the implication to green related indices and infrastructure	Provide GIC facilities and open spaces related KPIs		
	Connectivity Analysis			Conduct walkability and connectivity analysis to enable better pedestrian network planning in NDAs or redevelopment areas	Factor in GIC facilities and open spaces used by various groups of people (e.g. elderly, disabled, students, etc.) in the walkability and connectivity analysis		Extend walkability analysis to cover underground space, and assess connectivity between underground and aboveground space		Analyse correlation between walking comfort and green infrastructure	Display the walkability score and related KPIs		Provide baseline connectivity related results, and link up with the possible PIA in future
	Visualization and Analysis of Underground		Provide underground space information	Provide functions to support underground	Provide functions to identify available spaces for potential					Provide visualization images, 3D views, etc. of		

	Space and Utilities			space and utilities planning	development of underground GIC facilities					underground planning projects		
	Compliance Checking of Building Plans			Compliance checking function of other relevant regulations and guidelines (e.g. HKPSG)	Extend compliance checking function to the projects relating to GIC facilities (e.g. fire safety, E&M provisions)				Compliance checking function of other relevant regulation and guidelines (e.g. green ratio of HKPSG)	Provide visualization images, 3D views, etc. of building projects		
	Visualization and Analysis of Urban Green Infrastructure			Provide function to support green related analysis		Analyse correlation between green infrastructure and walking comfort		Incorporate the latest green infrastructure for related compliance checking		Display green related indices and KPIs in 3D views or dashboard		Analyse correlation between green infrastructure and other environment-related variables such as micro climate, air quality, psychological and psychiatric health, etc.
	Built Environment Information Dashboard											
	Workflow Management Platform											

Table 4.26 – Interfacing of Functions and Data among Recommended BEAP Applications

4.15 Potential Linkages between BEAP and Other Systems and Platforms

4.15.1.1 Subject to the further studies, it is envisaged that there would be linkages or interface between the 10 prototype applications and the systems/platforms developed by various B/Ds or parties. **Table 4.27** highlights some examples, which are not exclusive, for illustration purpose. As BEAP will directly rely on the CSDI for data provision, the datasets under these systems and platforms would be obtained via the CSDI.

4.15.1.2 The data linkages for the BEAP and the CSDI should be further reviewed and refined in the implementation stage, subject to the detailed design of the platform and each application.

Parties	Potential Linkage with Other Systems and Platforms	Datasets/ Information	Applications									
			Landuse Monitoring and Analytics	Site Search	Scenario Generation for Planning and Development	GIC Facilities and Open Space Analysis	Connectivity Analysis	Visualization and Analysis of U/G Space and Utilities	Compliance Checking of Building Plans	Visualization and Analysis of Urban Green	Workflow Management Platform	Built Environment Information Dashboard
LandsD	GeoInfo Map#	Public facilities				✓	✓					
	3D digital map	External and internal digital map of building and infrastructure, 3D pedestrian network			✓		✓	✓		✓		
PlanD	GeoIinfo OneStop (GOS)# / Statutory Planning Portal 2 (SPP2)#	Statutory planning information (e.g. applications for planning permission, representations/objections to statutory plan and rezoning / amendment of plans, etc.)			✓	✓		✓	✓	✓	✓	
TMO	Tree Management Information System (TMIS)#	Tree information					✓	✓		✓		
TD	Intelligent Road Network (IRN)#	Road network			✓	✓	✓					

Parties	Potential Linkage with Other Systems and Platforms	Datasets/ Information	Applications									
			Landuse Monitoring and Analytics	Site Search	Scenario Generation for Planning and Development	GIC Facilities and Open Space Analysis	Connectivity Analysis	Visualization and Analysis of U/G Space and Utilities	Compliance Checking of Building Plans	Visualization and Analysis of Urban Green	Workflow Management Platform	Built Environment Information Dashboard
	Road Traffic Information Service (RTIS) #	Traffic and transport information including real-time traffic snapshots and webcast, journey time, traffic speed maps					✓					
	HKeMobility#	Integrated public transport, walking and driving route search; and one-stop transport and traffic info					✓					
	Walkability	Results from the related Walkability studies					✓					
BD	BDGIS#	Building works related information (e.g. new buildings, worksites, railway zones, etc.)			✓			✓				
	ESH	Submitted building plans							✓			
DSD	AM/FM#	Drainage asset inventory record			✓			✓				
WSD	DMS#	Water mains record plan and related spatial data			✓			✓				
HKUST	PRAISE-HK#	Real-time air quality information down to street level					✓			✓		
# Existing systems / platforms												

Table 4.27 – Interface between Recommended BEAP Applications and Existing Systems/Applications Developed by B/Ds or Other Parties

4.16 Prototype Applications with Potential for Public Use

4.16.1.1 Among all the 10 prototype applications, taking into account the functionality, wider benefits to the users, public interests, and ease of access or operation, etc., it is concluded that the following two applications have the greatest potential for further extension for public use.

4.16.2 Visualization and Analysis of Urban Green Infrastructure

4.16.2.1 The public can contribute to updating tree and vegetation location data (e.g. planter locations, incorrect tree locations, etc.).

4.16.2.2 The application can be a tool for education purpose, allowing a better understanding of the effects of urban greening and providing researchers with a source of green-related data. The application also provides a platform for the students to visualize the correlation between green infrastructure with the urban environment (e.g. existing vegetation with anthropogenic heat).

4.16.2.3 The functions of the application can facilitate better landscape planning, designing planting schemes and enhancing local environmental quality through the visualization and analysis of the green-related data derived from academia or other stakeholders such as carbon absorption of trees and the local green factor. Subject to further investigation, due consideration can be given to collaborate with the academia to host this application, just like AURIN of Australia.

4.16.3 GIC Facilities and Open Space Analysis

4.16.3.1 Users can visualize the spatial distribution of GIC facilities together with their attributes to assist them in making decisions on the residence and choice of access to the public services. The application may also serve as a platform to allow exchange of ideas between the general public and relevant B/Ds.

4.16.3.2 Through the application, information on GIC facilities such as vacant school sites can be included to allow general public to contribute ideas on potential uses of the site and give opinions on the local community needs, enabling B/Ds to better design facilities tailored towards the local community.

4.16.3.3 In future, if the datasets of the GIC facilities have embraced the real-time data such as the occupancy rate of hospital beds, which would provide useful information for the general public to make better choice of community services.

5 RECOMMENDATIONS FOR SETTING UP A BEAP FOR HONG KONG

5.1 Implementation of BEAP

5.1.1 Overview

5.1.1.1 Following the conceptual model and four building blocks as set out in Stage 1 of the Study, the implementation of the BEAP can be further divided into two levels of development – "Platform" and "Application", which are shown in **Figure 5.1**:

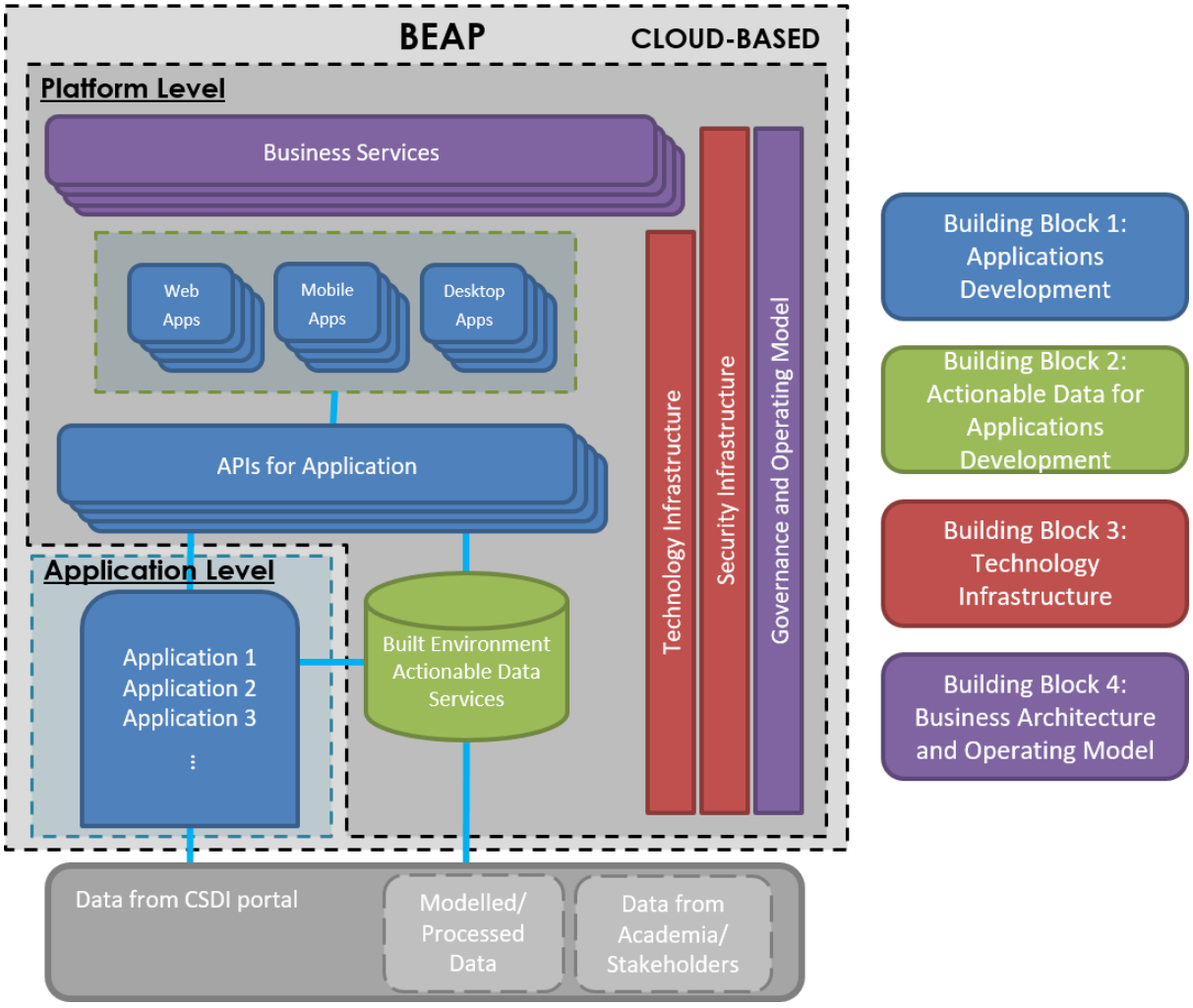


Figure 5.1 – BEAP Conceptual Model

5.1.1.2 For future implementation of the BEAP, it is recommended to adopt two levels of development: "Platform" and "Applications". Currently, the Hong Kong GeoData Store launched by LandsD in December 2018 will be used as the foundation for development of the CSDI portal (i.e. alpha version of the CSDI). Between now and 2022, it is planned to transform the Hong Kong GeoData Store into the official CSDI portal with initial focus on spatial data held by DEVB's family of departments. Against this, it is considered that the implementation stage for the platform development can be divided into two phases:

- Short Term – To set up and operate an up-and-running BEAP with the development of prioritised applications
- Mid-Long Term – To continue developing and linking up more built-environment related applications with further scale up as well as to establish an eco-system among the B/Ds and relevant stakeholders or academia for evolving application development

5.1.1.3 With an aim to meet different B/Ds, business, research and public users' needs for both platform and application development levels, it is recommended to outsource the implementation of the BEAP and the applications while in-house team can play a supporting role to manage the whole process. An in-house team for BEAP development is essential to help monitor the quality, progress of works, and to facilitate the coordination works among B/Ds. The BEAP team will also perform the function of knowledge succession to provide necessary support to the on-going enhancement of the BEAP. Outsourcing services to develop the functions and applications of BEAP would help to ensure flexibility in human resources and ease to mobilize different aspects of expertise during implementation in deploying the latest technologies from the market. During the implementation stage, further liaison with relevant B/Ds such as DEVB, ITB, CSDSC and its working groups on the development of the BEAP and the recommended BEAs including the quick-win projects would be required.

5.1.1.4 The ensuing sections list out the key requirements/considerations for the implementation of the platform and applications to support the BEAP.

5.1.2 Implementation at Platform Level

Principle Design and Development Requirements

5.1.2.1 Based on the review on the overseas experience and the latest technology development in Stage 1 of the Study, digital twin technology is being used increasingly to provide three-dimensional virtual replica of a physical system or an object. Adapted to urban scale, a common (or single) digital twin platform is provided to collate the virtual replica of different urban planning, infrastructure and assets (e.g. mobility, utilities, security, energy, water, building, etc.), to enable visualization and representation of various aspects of urban and built environment information in a 3D environment. Therefore, along with the 2D spatial data and 3D model provided by the CSDI, the BEAP should combine with the latest state of the art technologies such as 5G, photogrammetry, artificially intelligence, machine learning, sensing systems, IoT, etc. in its digital twin platform, and further evolve from traditional ideas of "information map" or a "3D model for visualization" into an analytic platform with various applications of various service domains, a dynamic type monitoring system and their interactions within a city urban built environment.

5.1.2.2 On the basis of the mission, objectives and principles of the BEAP set out in Stage 1 (see **Section 3.1**) and its relationship with the CSDI, the planning, design and development at platform level for the implementation of BEAP should adhere to the following requirements:

- Interface and evolve along with the CSDI, and harness the CSDI datasets based on established data exchange and sharing practices;
- Be scalable (more users), expandable (wider coverage areas and even for the whole territory) and extendable (embracing more applications);
- Use and integrate both GIS and BIM oriented software as the backbone of the platform, and be flexible through embracing the concept of open standards to integrate with different design GIS oriented software (ArcGIS, SuperMap, QGIS, etc), BIM oriented software (e.g. Bentley, Autodesk Revit, Catia, ArchiCad, Sketechup, etc), other relevant software, plug-ins and add-on modules;
- Establish a single management cloud platform to accommodate data from different software platforms and APIs from external platform (e.g. the CSDI, the Government PSI portal, etc.);
- Be simple and easy to use to increase usability;
- Be cost effective;
- Be capable of taking full advantages of technologies (e.g. big data analytics, machine learning, 3D digital technology, etc) in supporting functional development of various applications;
- Be available and able to realize its benefits earlier;
- Fully utilize built-in functions and flexibility of software packages to shorten development time and make upgrade easier;
- Continuously evolve and adopt an incremental and building block approach for implementation; and
- Cross-reference to the well-established international practices and experiences.

Key User Groups of BEAP

5.1.2.3 The target users of the BEAP include internal users from B/Ds, external users from academia (including universities and research institutes) and industry users (including various relevant professional sectors), BEAP administrators who are responsible for daily system administration and maintenance of the system, as well as the public user in longer term.

Key Functions of BEAP

5.1.2.4 Among all applications, there are many functional requirements being common and similar. From the perspective of the management and operational effectiveness and efficiency, these functions could be built-in and provided at the platform to support and facilitate development of various applications, and more importantly to enhance the user experience in using data and the applications under the BEAP. Having said that, BEAP would align with the CSDI during the course of implementation and ensure the functions provided by the two platforms would not overlap with each other, avoiding any potential duplication of effort. In future, when the CSDI portal can provide all the functions required by the BEAP at platform level, subject to the platform architecture design, there may have potential to integrate BEAP with the CSDI portal. These functional requirements are categorized as follows:

- System Administration
- General Query and Analysis Functionality

- 3D and Digital Twin Management
- Geo-Information Management
- Audit, Control and Security Management

5.1.2.5 For each category, recommended for each category of requirements are shown in **Table 5.1**:

Requirements of Each Category	Functions
(a) System Administration	
(i) Administrative Function to Manage the User Accounts and User Access Rights of Data and Functions	Allow administrator to manage the user accounts and user access rights of functions and actionable datasets under various applications.
(ii) Provide System Monitor Function to View Web Access Statistics and Monitor System Healthiness	Provide system monitor functions to view web access statistics and monitor system healthiness (e.g. whether the system services are started and running, number and activity level of concurrent users, etc.).
(iii) Provide System Management Tools for House Keeping and Change System Properties	Provide system management tools for system housekeeping (e.g. clearing log files) and change system properties (e.g. system timeout).
(iv) Provide System Statistical Reports for System Administration Purpose	Provide system statistical reports (e.g. users' access statistics) for system administration purpose.
(v) Provide administrative functions to publish and manage BEAP applications	BEAP administrators need to be able to publish and manage new applications, including verifying dependencies, establishing permissions and updating application catalogues.
(b) General Query and Analysis	
(i) Search Documents by Keywords or Description	Search document by content (i.e. keywords) or description. The documents listed in the result window should be able to be retrieved.
(ii)Search Map Layers by Layer Name or Description	Search map layer by layer name or description. The layers listed in the result window should be located in the table of content and set visible.

Requirements of Each Category	Functions
(iii)Search Aerial Photos or Other Images by Name or Description	Search aerial photos or other images by name or description. The images listed in the result window should be able to be retrieved.
(iv)Search Address and Spatial Data by Keywords	Provide an integrated keyword search on multiple datasets such as names of building, places and villages and their addresses. Users should be able to view the location of data through the map when selecting any record in the search result list.
(v)Search on Spatial Datasets by Combination of Different Criteria	Provide advanced map search function for searching different datasets by building up query with different criteria.
(vi)Perform Spatial Selection on Multiple Feature Layers	Provide a selection tool to select features from multiple feature layers.
(vii)Perform Buffer Search based on Selected Features or Drawn Graphics	Select features from multiple layers by buffering a user defined point, polyline, polygon or selected map features.
(viii) Export Textual Search Result to Spreadsheet Format	Search result in textual format should be allowed to export in spreadsheet format such as CSV or equivalent format.
(ix) Provide Dashboard Summary for Showing Management Statistics for Useful Information	Provide dashboard summaries to show management statistics of useful information generated from applications.
(x) Generate Useful Summary Reports with Predefined Layout	Provide summary reports by retrieving results/information from applications with pre-defined layout.
(xi) Provide API to support development of new applications.	Provide APIs that expose BEAP functionality to enable application developers to build applications on top of the BEAP.
(c) 3D and Digital Twin Management	
(i) Import, Manipulate and Visualize Existing 3D Digital Model, Data and Objects	Provide a module/interface to import, manipulate and visualize existing 3D digital models, data and objects such as DTM/DSM/DEM with orthophotos, buildings, street furniture, etc. Users should be able to import 3D data and associated attributes under common 3D and BIM file formats such as 3ds, DWG, DGN and IFC; and explore 3D features, such as terrain and elevation from all angles and choose specific layers to view.

Requirements of Each Category	Functions
(ii) Manipulate and Visualize Proposed 3D Building Models	Provide a module/interface to manipulate and visualize proposed 3D building models (such as new development proposals/options) and its attribute data.
(iii) Integrate 2D GIS spatial/attribute data	Provide a module/interface to integrate various 2D GIS spatial/attribute data.
(iv) Perform query and analysis of 2D/3D spatial/attribute data in 3D environment	Provide a module/interface to perform query an analysis of 2D/3D spatial/attribute data in 3D environment.
(d) Geo-Information Management	
(i) Provide an interactive map comprising of data	Provide GIS map function to visualize spatial data from various GIS and related platforms and infrastructure. Provide map navigation control including Map Zooming Control, Zoom to Defined Map Scale, Display Full Extent, Display Previous Extent, Display Next Extent, and Pan Map, etc. Allow to display easting and northing coordinates on map by mouse cursor.
(ii) Control Map Layer Display Property	"Display" functions should include: - Enable/ disable the visibility of the map layers in the table of content; - Adjust the transparency level of layers displayed on map until the map display is best suited to user's needs; - Adjust the display sequence of the map layers in the table of contents; and - Interact with two web maps or two layers of a single web map. The tools are efficient to compare two different maps (e.g. before-and-after imagery) without turning on/off the layers.
(iii) Change Map Display Theme	Allow switching to display digital orthophoto or other thematic map.
(iv) Display Dynamic Map Legend and Overview Map of the Interactive Map	Provide an overview map to help orient user by showing the location of current view in the context of a larger geographic area; and view the dynamic legend information relating to the layer currently visible in the map.
(v) Data Measurement and Analysis tools	Data measurement and analysis tools should include: - Extract: The Extract tools let you select features and attributes in a feature class or table based on a query (SQL expression) or spatial and attribute extraction. The output features and attributes are stored in a feature class or table;

Requirements of Each Category	Functions
	- Overlay: overlay multiple feature classes to combine, erase, modify, or update spatial features, resulting in a new feature class. New information is created when overlaying one set of features with another; - Proximity: determine the proximity of features within one or more feature classes or between two feature classes; and - Calculation and measurement: perform standard statistical analysis (such as mean, minimum, maximum, and standard deviation) on attribute data as well as tools that calculate/measure area, length, and count statistics for overlapping and neighbouring features.
(vi) Draw Graphics with Different Shape and Placing Text/Icon on the Map with Redlining Functions	Draw directly on map including point, polyline, polygon, circle, ellipse, text or defined user icons.
(vii) Identify Feature Information on Map	Provide "identify" function to display map feature's information on map and retrieve detailed information and related documents. The function should allow users to export the queried data in local computer for advanced processing by the user.
(viii) Print Map with Predefined Layout	Export the current map to PDF with predefined layout templates. The paper size of the layout should be in various size with Portrait or Landscape orientation. The exported PDF should, at least, include date, copyright and drawings drawn by users.
(ix) Save and Share Current Map View as URL	Share the map currently viewing to other users through an URL link. The same map (such as location, level of scale, layer's visibility, query and selected features) should be displayed to the recipient users when the URL is opened.
(x) Save and Share Comment on the Spatial Context	Provide geodesign collaboration function for communicating comments on the design of infrastructure and buildings against development restrictions such as those imposed by Layout Plans, Outline Development Plans, land lease conditions, and approved building plans and other relevant restrictions from related B/Ds.
(xi) Provide input and output	Provide import and export geospatial information from various GIS and related platforms and infrastructure in operation [Remark: The "Import" function should support the following spatial data format as a minimum: Esri File Geodatabase (GDB), Esri shapefile, MicroStation DGN, AutoCAD DWG, Oracle Spatial, ArcInfo Interchange Export

Requirements of Each Category	Functions
	file (e00), Geography Markup Language (GML), LAS for 3D point cloud, point cloud in ASCII.]
(xii) Provide a Public Platform for Information Dissemination	Establish a public platform (e.g. a public website) for public use. Function and data access level will be subject to each application.
(xiii) Adopt W3C WCAG 2.1 Level AA in the Web Platform	The website should conform to WCAG 2.1 Level AA Standard (or the most updated version) as far as possible.
(xiv) Provide Online Help to the Web System	Provide a help manual in the web system to support users.
(xv) Provide Hyperlink to Documents or External Websites Related to the System	Allow users to retrieve documents or redirect to external websites related to the System by hyperlink.
(xvi) Provide Data Update Information to Various Dataset Stored in the System	Allow users to find the last update date of the spatial data stored in the system.
(xvii) Provide Notice Board to Display Ad hoc System Information to Web Users	Provide a notice board to display instant information such as "Latest Functions", "Latest Actionable Dataset", "Out-of-Service" and "Service Maintenance" after user login into the system to inform users of service status and other announcements.
(e) Audit Control and Security	
(i) Provide Access Control	Provide access right maintenance program to allow administrators to maintain access rights and their corresponding accessible features or multimedia file by individual user account or user group
(ii) Provide Audit Control	Provide and keep track of user's activities information and allow administrator to query the audit log and display the audit log for login usage, function usage, document access and spatial layer access
(iii) Comply with relevant security requirements	Meet the required IT security requirements according to the restricted classification of data stored. The system must conform to the OCGIO Security Regulation and IT Security Policy and related Guidelines.

Table 5.1 – Functions of Each Category of Requirements for BEAP

Web Portal under the Platform for Applications

5.1.2.6 All applications which are common with value/benefits to multiple agencies or will be frequently used by different B/Ds would be hosted in the BEAP to facilitate browsing, query and analysis of various users. Apps approach is recommended to be adopted to facilitate organizing all applications with different levels under respective apps within the web portal for easy access. The web portal would

provide a single point of access (or support "single-sign-on" feature[52]) and front-end interface for users. Users are not required to login and remember the web addresses of each application, and would be able to directly access different applications and the platform using the common interfaces via web browsers without installation of any plug-in or other execution scripts on individual desktop computer or workstation. Under the BEAP environment, the users are able to browse, search and use the common functionality of the platform, as well as to open particular apps to access the readily available functions of the applications or retrieve any data accessible by them.

5.1.2.7 The contractors of the platform and application should work together to organize all functions into different apps according to the nature of each application. Apps for each application refers to a web-based application which can support the web browsers of both Windows based PCs, as well as iOS and Android powered devices and if necessary mobile phone.

5.1.2.8 To align with the above design and planning principles for apps approach, the following technical requirements for setting up the platform are recommended. The platform should:

- Comprise a web portal to host and disseminate different levels of apps, which would be developed and scaled up with corresponding and related functions and services according to the development stages
- Support the latest geo-spatial, GIS, BIM and 3D model data as well as big data and related web technologies. Configuration instead of customization should be adopted as far as possible to reduce the time and efforts for developing apps
- Be scalable to meet the requirements of more B/Ds users. A multi-tier application architecture design should be adopted to incorporate components of different applications in different tiers of the architecture to allow easier scale-up. Subject to the demand and development needs, more hardware and software resources can be increased to share the workload if a particular component is overloaded. The platform shall also be expansible and extensible to cope with the wider usage and applications in more districts, regions or even the whole territory.
- Be extensible to incorporate more different apps. The platform services should be able to extend to cover mobile or desktop devices. As such, the functions and services from the web portal can be consumed to create a new mobile or desktop applications in the future
- Ensure that proper access control is enforced to manage the privileges and access rights of the users.

<u>Data Management and Interface with the CSDI</u>

5.1.2.9 According to the BEAP conceptual model, the BEAP is not a data preparation and storage platform, but mainly to provide a set of applications with functions and tools for data visualization and analysis to support the CSDI. The BEAP should link to and interface with the CSDI portal to obtain the required data for the applications. It is also assumed that the CSDI would set up a centralized conversion

[52] SSO is an authentication service that permits a user to use one set of login credentials (e.g., name and password) to access multiple applications.

engine to process GIS and spatial data in various formats from various B/Ds to a standard format specified under the CSDI. The BEAP, therefore, would add value for built environment professionals by presenting a set of applications that consume data from the CSDI. In this regard, it is anticipated that the CSDI would provide:

- web map services and API such that BEAP can directly use the services and integrate into its system; and
- Actionable data API such that the BEAP is able to consume the required data directly from the CSDI.

5.1.2.10 With respect to data updating, as the data to be consumed by the BEAP will come solely from the CSDI which would be contributed by the B/Ds and be updated regularly, data integrity, accuracy and updatedness of the BEAP shall not be a problem.

5.1.2.11 Moreover, some applications under BEAP would generate useful information at different stages of application development which can also serve as additional dataset to support CSDI. For those data generated by the BEAP, if they are widely adopted and considered sharable, they will be fed back to the CSDI for sharing among B/Ds. Therefore, the in-house staff for BEAP should closely collaborate with CSDI team regarding the data format, accuracy, completeness and timeliness from application development perspective.

Interoperability

5.1.2.12 The OGCIO Interoperability Framework (IF) is primarily a collection of guidance documents, standards, and specifications that help B/Ds define the interface between interacting applications. Computer systems implemented on different hardware and software platforms by different B/Ds can interoperate with one another by adopting the IF. BEAP should comply with the latest IF (currently version 18.0)[53], such that it can interoperate and have a better interface with other systems over a standard-based environment. Apart from local IF, the corresponding requirements from the Open Geospatial Consortium standards[54] should also be adopted.

5.1.3 Implementation at Application Level

5.1.3.1 With regard to the development of applications under the BEAP, detailed elaboration on the scope and functions of each prototype applications have been provided in previous chapters. With due consideration on the data availability, resources implication, interface with the CSDI as well as the maturity of the technology, it may not be possible or desirable to implement all applications in one-go. The following sections shed light on the key considerations in prioritizing the implementation of each application, the recommended implementation timeframe as well as the criteria for future built environment related applications to be put under the BEAP with view to facilitating the continual development of the BEAP to boost up the usage and benefits of the CSDI.

[53] https://www.ogcio.gov.hk/en/our_work/infrastructure/e_government/if/interoperability_framework.html
[54] https://www.opengeospatial.org/standards

Key Considerations for Implementation Prioritization of Applications

5.1.3.2 To accord the priority to implement the prototype applications in the coming years under the Application Plan, it is recommended to go through the following key considerations:

- *Application Area/Topic* – Whether the applications fall under the 3 thematic areas: Planning and Landuse; Infrastructure and Engineering; Landscape, Environment and Conservation as specified in the Study Brief. Applications need to respond to urgency of issues in the built environment. With sustainability and environmental awareness at the forefront, applications with the functions adequately addressing these issues and resource management will be deemed more desirable for implementation with high priority.
- *Fit with BEAP objectives* – Whether the applications encourage and foster high level of co-operation, collaboration and co-creation between B/Ds, business, academia and the public; improve efficiency, transparency and support for decision making in planning and development; take forward CSDI development strategy to support development of smart city initiatives; enable development and operation of built environment applications; provide a means to accessing built environment application; and provide a means for accessing actionable data.
- *Acceptance and Ease of Use* – The need for expertise and specific domain knowledge may obstruct the wider adoption of applications into operations. While user training and documentation can be provided, widespread usage of the application still hinges on whether it would be user-friendly and whether users can understand and operate the application easily without undergoing numerous hours of sophisticated training. Applications with simple operation, such as searching and visualization with clear on-screen instructions, which can be handled by the general users without much training involved, would be hence likely to be easily accepted and adopted into the working processes.
- *Wider Benefit* – Whether it is beneficial to the wider public and usable by a greater audience. While many applications are developed for enhancing B/Ds' operations and facilitate their works, some applications equipped with the functions that are of the interest to the public and uplift the quality of the services to the public should be accorded with priority for implementation. The applications involving information dissemination such as availability of services and resources are useful for the public as it can support daily tasks and planning of activities. Easy access to a pool of relevant data for researchers or academia can support undertaking of various researches and studies, which can help promote the development of innovative inventions, thus contributing to building up a smart city. Furthermore, applications with potential to be opened to the public, which can enhance communication between the Government and external parties and opening up channels for fostering collaboration with industries, professional organisations and academics, should also be accorded priority to the implementation.
- *Collaboration and Support from B/Ds* – Whether the applications can be used persistently and evolved continuously for perpetuation of further development and scale up. Applications, which are designed to be deployed in a persistent

manner and with continuous contribution in respect of the data update by users, will help further develop and evolve the applications to better support the business operations. Data updates and contribution can enhance analytical functions, producing more accurate and precise outputs while a large pool of the users can also generate more feedback on functionality of application, facilitating the upgrades and enhancements to strengthen the functions and support the development of the BEAP.

- *Data Readiness* – Whether the availability of required data and current technology maturity can support the operation of the applications. For example, in the absence of the sufficient real time IoT sensor or data, it would be difficult to support a real-time data analysis platform. Similar to the BIM data, most B/Ds at this juncture only have a limited number of or incomplete BIM models, which would dampen the development potential and utilization of BIM/GIS integration related applications. Availability of the incomplete datasets would cause a deficiency of information to support undertaking of analyses or assessments. For example, the information relating to the exact completion year of the buildings and population distribution at building block level are the essential data required for the development of applications involving the GIC facilities analysis, but currently unavailable.
- *Infrastructure and Support* – Whether the supporting mechanisms and IT infrastructure (e.g. telecommunication and connectivity), hardware and software are available to support the application development. Development and enhancement to the existing IT infrastructure would be indispensable to the success of the implementation of the applications, such as increase in the current speed of network and data transfer load while other supporting services, such as backend technical support and user training, will ensure operability and management of application such as the capability of existing backend web servers to host and manage multiple concurrent user access or speed of data retrieval and provision of tutorials or on-screen prompts for users. Furthermore, the Applications may also need to be backwards compatible as client hardware can be diverse and varied.
- *Scalability* – Whether the applications can demonstrate usability in smaller scale with the capacity to scale up in four different aspects in mid-long term: (i) functionality, (ii) data, (iii) spatial coverage, and (iv) user base. For example, the "Visualization and Analysis of Underground Space and Utilities" application can demonstrate the feasibility of being adopted for a small site area such as a NDA or a work site with some underground utilities alignments, with scale-up potential to extend the coverage of services area to the whole territory and incorporation of more underground-related datasets. Also, the functionality such as clash detection of underground utilities alignments and underground space volume calculation can be further developed and even be opened up for the use of non-government utilities companies in future. However, given the nature and scope of this application, the user base may be limited to the certain works departments such as HyD, and the benefit of this application may not be widely received by other departments or the general public. In view of this, it is recommended to implement this application in later stage.

- *New Technology* – Whether the applications would leverage the leading-edge technology development. Use of new evolving technology, such as AI, deep learning mechanism and parametric design, can test out its capability and limits, encourage technological innovation, and refine existing design to enhance efficiency. With the adoption of the latest technology, the functionality of the application can be kept up-to-date and be robust enough to meet the requirements arising from the ever-changing environment, and more importantly to sustain its applicability and operability to support the development of the BEAP.
- *Facilitating Implementation Programme of Development Projects* – Whether the functions of the applications would facilitate the implementation of development projects. For example, the NDA projects can be benefited from the support of the applications, which provide the function of retrieval and visualization of required data contributed from various B/Ds and automation of the workflow involving document management or circulation of plans/documents for comments. The overall implementation programme of development projects can be expedited when conventional workflow could be automated or streamlined through the web-based communication channel among multiple B/Ds as provided by the applications. Due consideration may be given to accord priority to implementing this kind of applications.
- *Interdependency between Applications* – Whether the applications would have dependency and interoperability of functions with each other. One of the key considerations for the implementation prioritisation of the applications would hinge on whether the operation of the applications would have any linkage with other applications or the performance of the applications can be enhanced by incorporating the processed results derived from other applications, which ultimately would create synergy effect to promote the wider usage of the applications under the BEAP. For example, the "Site Search" application is equipped with the function of searching sites based on predefined criteria and also have the capability of incorporating the results generated from other applications (e.g. "GIC Facilities and Open Space Analysis") to serve as additional searching criteria to enhance the output quality. The implementation priority of this application may be higher as compared with those without interdependence with other applications.

Implementation Phasing of Applications

5.1.3.3 Based on the above considerations, the timeline of application development is suggested as shown in **Figure 5.2**. The prioritization of implementing the 10 applications are recommended as follows:

Short-term as Quick-win Projects (by 2022/23 tentatively)

- GIC Facilities and Open Space Analysis
- Visualization and Analysis of Urban Green Infrastructure
- Site Search

Mid to Long-term

- Landuse Monitoring and Analytics

- Scenario Generation for Planning and Development
- Compliance Checking of Building Plans
- Visualization and Analysis of Underground Space and Utilities
- Connectivity Analysis
- Workflow Management Platform
- Built Environment Information Dashboard

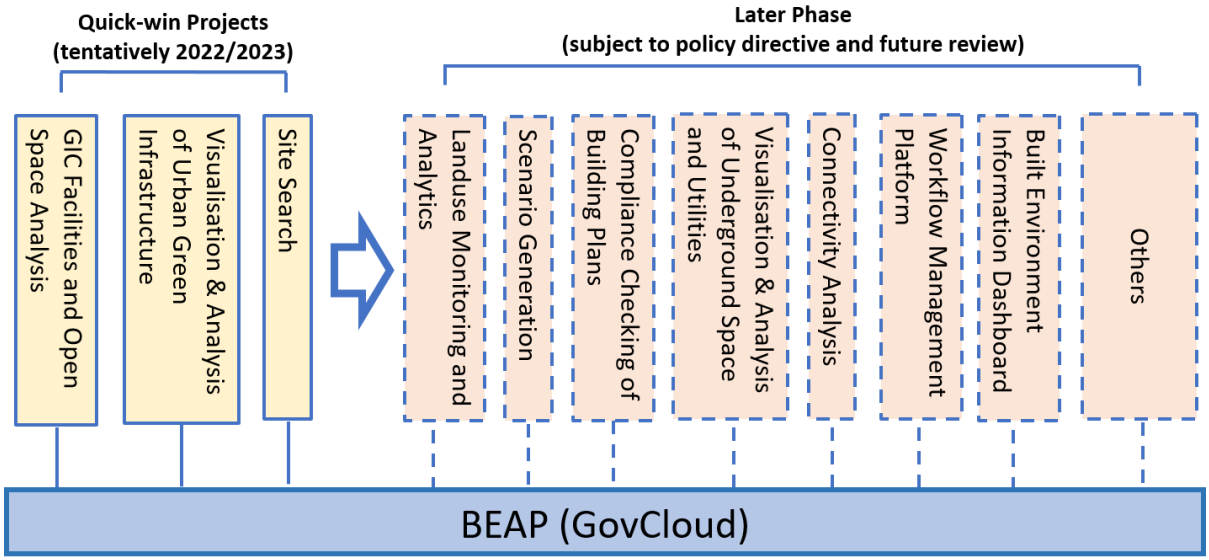


Figure 5.2 – Timeline of Application Development

5.1.3.4 Subject to review and policy directives, the remaining seven applications could be categorized as mid-long term projects and implemented by batches. Based on considerations of implementation prioritization as set out in Section 5.1.3.2, "Landuse Monitoring and Analytics", "Scenario Generation for Planning and Development" and "Compliance Checking of Building Plans" can be put forward first while the others would be accorded with lower priority for implementation. The comparison details of each application based on the above evaluation criteria are set out at **Appendix B**. Apart from the availability of the funding resources and manpower input, data readiness or whether the data required has been transformed into digital format i.e. machine readable or spatially enabled would be pivotal to the success of the implementation of these applications. It is envisaged that the empirical demonstration of the feasibility of these applications and their benefit to the business operation of B/Ds would provide a catalyst to relevant B/Ds and parties to take steps to review their datasets and also undertake necessary data conversion work to ensure data readiness to support the future implementation of these applications.

5.1.3.5 At the early implementation stage, the infrastructure of the BEAP with support of the software and modules installed in the cloud server can accommodate small number of applications. In the mid to long term, the hardware of the platform should be further expanded to cater for increasing number of applications and concurrent users.

<u>Criteria for Inclusion of Future Built Environment Applications under BEAP</u>

5.1.3.6 The success of the BEAP would depend on the collaboration, co-creation and co-sharing of various applications between different parties. The BEAP would provide

a platform for all built-environment related applications shared by B/Ds or later in a wider context among the business, academia and the public. Through the BEAP, an eco-system would be created with the use of different technologies and applications such as BIM, remote sensing, data analytics, scientific modelling and other geospatial systems, where B/Ds, academia, professionals, business and different sectors of the community can co-operate, collaborate and co-create under the atmosphere, creating synergy effects and boosting up the usage and benefits of the CSDI. Therefore, when the BEAP is in place, not only B/Ds, but also the researchers from local universities and private sector should be encouraged to share their R&D results and applications via the platform.

5.1.3.7 At a strategic level, a practice or mechanism should be established to facilitate both B/Ds and external parties to collaborate and co-operate to develop common built environment related applications to support the BEAP. It is considered that the future applications can be put under the BEAP through the following schemes:

- Application Development Scheme:
    - Users to develop an application by making use of the functions of the BEAP and integrate with the applications currently in operation.
- Application Interfacing Scheme:
    - Users to link up or interface their corresponding applications with the BEAP; and
    - Users to share and update sharable datasets through the CSDI Portal in the form of API.

5.1.3.8 To ensure the quality of the applications in respect of the interoperability and functionality and in line with the purpose of the BEAP focusing on the built-environment aspect, it is recommended that the following criteria should be taken into account in considering whether the future applications developed by other B/Ds or parties/organisations, can be incorporated into the BEAP for shared use:

- Nature of the Application:
    - Whether the application is in line with the key themes of the BEAP (i.e. planning and landuse, infrastructure and engineering, landscape environment and conservation) of built environment;
    - Whether the application is relevant to the overarching policy directive and the Government initiatives in promoting smart city development;
    - Whether the application contributes to the improvement and upgrading of the industry in terms of planning, design and operation of various aspects in the built environment;
    - Whether the application opens up for more research opportunities and provides opportunities for training of local research and scientific personnel;
    - Whether the target outcomes (contents, functions and new dataset generated) of the application would foster co-operation, collaboration, and co-creation among Government, business, academia and research institutes, and attract more users in terms of quantity and diversity; and

  - Whether the target outcomes generated by the application would bring about wider economic and social benefits to the community.

- Technical considerations:
  - Whether the application proponent and the project team would possess sufficient domain knowledge or expertise to deliver the application on the technical side, which can be assessed based on the experience of the project team and feasibility of the project work plan;
  - Whether the application proponent and the project team have relevant previous experiences and track records;
  - Whether the application is developed based on the existing infrastructure and technology; and
  - Whether the existing hardware and software infrastructure of the BEAP are sufficient to cater for the technical requirements of the application development and the future scale-up potential (e.g. increase in users, usage rate, etc.).
- Financial and Management considerations:
  - Whether the overall planning and organizational structure of the application proponent and the technical and project management capability of the project team (e.g. the project team members' experience, qualifications, track record, and the resources available for the project, etc.) are considered sufficient for developing and maintaining the operation of the application;
  - Whether the development of the application has obtained the financial support from the relevant B/Ds (e.g. ITF) or other sources such as universities, business contribution, venture capital, etc.; and
  - Whether the budget, project expenditure and programme for the development of the application are reasonable and realistic.

5.1.4 Technology Infrastructure and Requirements

Overview

5.1.4.1 To achieve full interoperability among different BEAP components and external systems, it is recommended that the overall BEAP design should be service-oriented. The approach of Service Oriented Architecture (SOA), emphasizing loose coupling between services, should be addressed. The benefit of a loosely coupled system would be its agility - the ability to accommodate changes in the structure and implementation of the internals of a service to serve the business needs. While the application services of BEAP can serve for different evolving applications, new services are foreseeable and can also be defined to meet a particular need or when new actionable data is available in the future. SOA are a more agile alternative to the more tightly coupled object-oriented models. While SOA systems may have individual services that are built using object-oriented technology, the overall system design is service-oriented.

5.1.4.2 Under the BEAP, services can be adopted for both internal and external communication. For internal communication, various components of applications can communicate and deliver information to each other. The application server can

get the data from database server and disseminate the map services through web server and consumed by various applications. For external communication, users can retrieve information, perform query, visualization and analytics by calling the web server. This allows BEAP to reuse relevant services and easy to expand to cater for future business need.

5.1.4.3 The following sections recommend the key items of technology infrastructure and the corresponding requirements. It covers the following:

- Platform
- Hardware
- Software
- Network
- System Reliability and Resilience
- Backup and Recovery
- Data Retention and Archive
- Security and Access Control

Platform

5.1.4.4 Platform refers to the physical environment hosting BEAP. BEAP components can be installed in one or many physical servers similar to most of the traditional solutions or installed in virtual environment which is the trend of IT solution in recent years. Virtualized servers will not only provide a greener environment by sub-dividing the server compartments for different virtual servers, but also provide higher protection against hardware failure.

5.1.4.5 In the past, the consideration focus will be put on the trade-off between the virtualization benefit and the performance impact when running software in a virtualized environment. But recently, with the advance in virtualization technology, there is little or no decrease in overall performance when comparing running the application in physical servers. By considering the benefits brought by virtualization such as improved management, availability, and scalability, virtualized platform is recommended to host BEAP. There are two options in running the virtualized platform for BEAP, which can be compared in terms of cost effectiveness, easiness of set up and management efficiency:

- *On-premise*: Ride on the upgraded hardware infrastructure in existing infrastructure of respective department (e.g. PlanD) by expanding CPU power, memory and storage to cope with increasing BEAP hardware requirements;
- *GovCloud*: Employ the Government Cloud (GovCloud) computing services as an external resource to host the BEAP.

5.1.4.6 Utilizing the GovCloud would enable ease of setting up, as most of the resources are readily available over the cloud and can be expanded if required. GovCloud is able to provide a large scale, secured and distributed cloud computing infrastructure, as well as to attain a higher degree of resilience (storage/network), security, scalability and expandability according to the needs of different government departments' users.

5.1.4.7 Therefore, riding on GovCloud with virtualization technology is recommended a more favourable option. The actual cost is subject to the service package provided by OGCIO. It is also noted that OGCIO might be able to offer a more cost-effective package for respective department, comparing to other cloud service providers of the market.

5.1.4.8 Both production environment (stage) and staging environment (stage) are suggested for BEAP.

- *Production environment*: a term used mostly by developers to describe the setting where software and other components are actually put into operation for their intended uses by end users; a production environment can be thought of as a real-time setting where all functions of BEAP are up-and-running and hardware setups are installed and relied on for organization or commercial daily operations.

- *Staging environment*: a nearly exact replica of a production environment for software testing. Staging stage are made to test codes, builds, and updates to ensure quality under a production-like environment before application deployment. The staging environment requires a copy of the same configurations of hardware, servers, databases, and caches. Everything in a staging environment should be as close a copy to the production environment as possible to ensure the software works correctly.

Hardware

5.1.4.9 The hardware for the BEAP would be able to cater sufficient computational processing power and space to store actionable data and newly generated datasets.

5.1.4.10 Considering that different levels of B/Ds users will access the BEAP and various applications on ad hoc basis in both the office hours and non-office hours, the BEAP should be available to end users 24 hours per days and 7 days per week except during the maintenance period with prior notice. Resilient hardware should be available to support high service availability.

5.1.4.11 Taking into account the target users of each application, there would be over 20 B/Ds to use the applications or services in the BEAP including senior management, professional and technical staff. At the initial stage of the BEAP, it is assumed that there would be a few numbers of concurrent users (say about 5 of each B/Ds) and thus come up with around 100 concurrent users for using the platform services and applications under the BEAP. In mid-long term, with the increase in the applications to be deployed under the BEAP, the number and type of concurrent users would also be increased. The estimated number of users of the BEAP in short-term are summarised as below:

- Total users: No exact limit (mainly for B/Ds users at initial stage)

- Concurrent users: ~100 (short term)

5.1.4.12 It is agreed that the BEAP will operate under the umbrella of the CSDI and the data to be consumed by the BEAP will come from a single source (i.e. CSDI). It is anticipated the dataset volume to be stored in the BEAP would not be excessive as most data can be consumed from CSDI through API, and the key datasets kept in the BEAP should be related to the actionable and new modelled/processed datasets generated from the applications. In the long run, the following specific spatial and non-spatial data, which are expected to have a great data size, would be required.

As such, the BEAP should also be equipped with sufficient data storage hardware and CPU processing power for management of these data.

- Satellite images, aerial photos and site photos for "Landuse Monitoring and Analytics" or any similar applications
- BIM models and related data for "Compliance Checking of Building Plan" or any similar applications
- Social media and social network data (including sound, picture, video stream and text message)
- Real time data from IoT and sensing systems

5.1.4.13 To meet resilience requirement, a multiple server architecture in cloud platform is required to accommodate different components, and to avoid single point of failure. The following virtualized server types are recommended to support the operations of BEAP:

- *Web server*: To host the web portal and provide communications with web clients/users through the network
- *Application server*: To host all related software and enable corresponding functionalities
- *Database server*: To store and retrieve actionable data and temporary data
- *File server*: To store all the files for users to upload and download files from BEAP
- *GPU server*: To support graphical and 3D display and visualization, as well as potential deep learning and AI functions

5.1.4.14 To set up the BEAP, there would be two stages: Production and Staging. Once the platform development is satisfied, the developed BEAP can be moved to a staging server. The staging server is a mirror copy of the production server, which its primary purpose is to test the completed BEAP development on a mirrored copy of production, which no actual code development on the staging server is needed. The staging server, therefore, is the last step before the BEAP is ready for deployment to a production server. The indicative hardware requirements for developing the BEAP in implementation stage are listed in **Table 5.2**:

	Short Term		**Mid/Long Term**	
	Production	**Staging**	**Production**	**Staging**
Web Server	- 4 Cores CPU or higher - 32GB RAM or more - No. of VM: 1	- 4 Cores CPU or higher - 32GB RAM or more - No. of VM: 1	- 6 Cores CPU or higher - 32GB RAM or more - No. of VM: 1	- 6 Cores CPU or higher - 32GB RAM or more - No. of VM: 1
Application Server	- 8 Cores CPU or higher	- 8 Cores CPU or higher	- 12 Cores CPU or higher	- 12 Cores CPU or higher

	Short Term		Mid/Long Term	
	Production	**Staging**	**Production**	**Staging**
	- 64GB RAM or more - No. of VM: 1	- 64GB RAM or more - No. of VM: 1	- 96GB RAM or more - No. of VM: 2	- 96GB RAM or more - No. of VM: 1
Data Server	- 8 Cores CPU or higher - 64GB RAM or more - No. of VM: 1	- 8 Cores CPU or higher - 64GB RAM or more - No. of VM: 1	- 12 Cores CPU or higher - 96GB RAM or more - No. of VM: 2	- 12 Cores CPU or higher - 96GB RAM or more - No. of VM: 1
File Server	- 4 Cores CPU or higher - 16GB RAM or more - No. of VM: 1	- 4 Cores CPU or higher - 16GB RAM or more - No. of VM: 1	- 6 Cores CPU or higher - 16GB RAM or more - No. of VM: 1	- 6 Cores CPU or higher - 16GB RAM or more - No. of VM: 1
GPU Server	- CUDA enabled NVIDIA TITAN V equivalent or above - 16 Cores CPU or higher - 64GB RAM or more - No. of VM: 1	- Not necessary	- To keep in view subject to technology growth and application development)	- Not necessary
Overall	- Storage: 5,000GB (total for all, minimum 1,000GB for GPU server) - Min no. of VM: 8		- 10,000GB (total for all) - Min no. of VM: 10	

Note: The above hardware requirements are indicative only. The exact requirements would be subject to the actual platform design and deployment strategies by the platform contractor in the implementation stage. Requirements will also be dependent upon the services and the flexibility available from the GovCloud.

Table 5.2 – Hardware Requirements for Setting Up of the BEAP in Implementation Stage

Software

5.1.4.15 The OS used in the BEAP must be 64-bit and supported in Virtualized Environment, as well as by the GIS and BIM oriented software.

5.1.4.16 The software of BEAP would enable to support scalable web architecture, different deployment scenarios and web configuration (such as single-tier, multi-tier, etc).

The functional requirements provided by the software under BEAP should follow those stated in **Section 5.1.2**.

5.1.4.17 The software would be hosted in GovCloud. It is assumed that GovCloud would provide the following "standard software":

- Microsoft Windows Server 2016 or any equivalent
- Microsoft SQL Server 2017 or any equivalent
- Vertias Backup Exec 20.4 or any equivalent
- Symantec Endpoint Protection 14 or any equivalent
- Microsoft System Center Operation Manager 2016 or any equivalent
- Microsoft Active Directory or any equivalent

5.1.4.18 Depending on the actual usage rate, in the case that the loading and usage of some particular applications under BEAP may be increased dramatically, but only in a relatively short period of time, all software used in the BEAP should have flexible term license arrangement to cater for this usage pattern.

5.1.4.19 The software requirements for the BEAP in the implementation stage are listed in **Table 5.3**:

	Short Term	**Mid/Long Term**
Software	- Microsoft Windows Server 2016 or any equivalent - Microsoft SQL Server 2017 or any equivalent - IIS 10.0 - Vertias Backup Exec 20.4 or any equivalent - Symantec Endpoint Protection 14 or any equivalent - Microsoft System Center Operation Manager 2016 or any equivalent - GIS-based software* - BIM-based software*	- Microsoft Windows Server 2016 or any equivalent - Microsoft SQL Server 2017 or any equivalent - IIS 10.0 - Vertias Backup Exec 20.4 or any equivalent - Symantec Endpoint Protection 14 or any equivalent - Microsoft System Center Operation Manager 2016 or any equivalent - GIS-based software with more plug-in modules* - BIM-based software with more plug-in modules*

Note: (1) Software marked with * to be provided by BEAP's contractor while others to be provided by GovCloud. (2) It should be noted that the above software requirements are indicative only. The exact requirements would be subject to the actual platform design by the platform contractor in the implementation stage.

Table 5.3 – Indicative Software Requirements for Setting up of the BEAP in Implementation Stage

Network

5.1.4.20 The overall design principle of the BEAP network shall provide accessibility, high performance, high availability, network security and scalability. BEAP accessibility is achieved by the web-based services orientated architecture such that authorized users may access to BEAP and its applications any time via browsers in their workstations.

5.1.4.21 B/Ds users can access and consume the BEAP services through Government network (i.e. GNET). In case B/Ds need to connect to BEAP over external networks, they must connect to the Government network through authorized Virtual Private Network (VPN) channel first (to provide strong authentication and encryption tunnel over network connection) before accessing BEAP. Antivirus software should be installed to all servers to detect and disinfect viruses with most up-to-date virus definition files provided by the software vendor.

5.1.4.22 To achieve high performance, fibre channel should be set up in connecting the Storage Area Network (SAN) to the data server. It provides a higher throughput than Ethernet network. Other network communication among the BEAP components should be supported by at least with Gigabit Ethernet.

5.1.4.23 To achieve high availability, the proposed network infrastructure should be designed to eliminate any single point of failure. Dual network devices should be configured in workload sharing and fault resilient mode.

5.1.4.24 In addition, all network equipment would support IPv6 for future expansion in the BEAP.

5.1.4.25 It is considered that 500Mbps is the minimum required bandwidth of GNET to support the network traffic of the BEAP while in mid/long term, with the increase in the users and the number of applications to be deployed, at least 1,000Mbps would be required to ensure smooth operation of the BEAP. Network options and costs will depend to a large extent upon the infrastructure services offered by GovCloud and the degree to which the network and networking components can be configured through software (software defined networking).

System Reliability and Resilience

5.1.4.26 In theory, system reliability is achieved by the sustainability of the service in the case of single point of failure. System architecture designed in high availability or with resilience will improve system reliability. High availability features such as redundant power supply, network cards, and hot-spare hard drives shall be specified for the BEAP to provide a stable computing environment for hosted applications.

5.1.4.27 Virtualized Technology: Virtual machines are used to provide higher protection against hardware failure. Features such as Virtual Machine High Availability (VMHA) could migrate all virtualized servers from a faulty server to another server within a couple of minutes to sustain the service. Containerisation should also be considered as a modern and flexible approach to application deployment.

5.1.4.28 Disk Storage Protection: Disk storage is usually protected by RAID configuration. SAN storage in RAID 5 or RAID 6 resilience should be provided. This configuration offers very high fault- and drive-failure tolerance even two simultaneous disks fail.

5.1.4.29 Business Continuity: Business Continuity Plan such as off-site backup and disaster recovery procedures should be prepared to maintain business continuity within the agreed tolerance level.

Backup and Recovery

5.1.4.30 All the BEAP servers will be set up with appropriate system and database backup/recovery services. It is recommended that the files and data backup should be performed daily. Moreover, the system should also execute full data and system backup job, which should be scheduled and performed weekly, monthly, yearly or before any changes and upgrade to system.

5.1.4.31 In case of unlikely event of disaster or severe system failure, full recovery of the entire system could still be possible. For the monthly and yearly backup, it is advisable to store backup copies at a safe and secure location remote from the site of the systems or conduct remote backup at off-site location. In case of any disaster which damages totally the systems, the data could still be reconstructed on similar computers elsewhere.

Data Retention and Archive

5.1.4.32 In general, the BEAP has a high frequency of data update since it generates newly datasets from various applications from time to time. Before the data is replaced by a new converted set, the previous data should be extracted and archived. At least one prior version of data should be kept for history tracking purpose.

Security and Access Control

5.1.4.33 Overall, BEAP's security should comply with the following:

- Government's Security Regulations
- Baseline IT Security Policy
- IT Security Guidelines
- The OGCIO IF
- Security Risk Assessment and Audit Guidelines

5.1.4.34 Major considerations regarding system security and access control are listed below:

- *Network security*: In term of network security, all the external interfaces of the BEAP should pass through a secured network with security measures such as outer/inner firewalls and intrusion detection system. For any external communication through the internet, two layers firewall as a De-Militarised Zone (DMZ) between the trusted zone of BEAP and the internet should be set up to prevent the BEAP internal network from being attacked by external parties. In later subsequent stages when public internet website is required in the BEAP, external firewall should be required to define the internet DMZ for the internet access. Intrusion detection service (IDS) and intrusion prevention service (IPS) are also required to detect malicious activities or policy violations.
- *Physical Security*: During the future implementation stage, subject to the detailed system design, the BEAP has to comply with all requirements on data security as stipulated in Government Security Regulations and the physical security of the BEAP should comply and commensurate with the security classification of the data it is holding. All production servers and equipment

should be hosted in the data centre inside locked room or cabinet, and should only be access by relevant personnel. The data centre should have proper environmental set up such as a raised floor, air- conditioning, emergency power generator, fire detection system, water leakage system, and other requirements that comply with OGCIO's Data Centre Site Preparation Guidelines.

- *Data Security*: The newly generated datasets in the BEAP should either be unclassified or classified as restricted. Classified data in whatever formats should be encrypted in storage and when transmitting over the network. No classified data should be transmitted from the BEAP to public through internet. Keys used for performing encryption (symmetric key only) or decryption must be kept secret, stored separately from the corresponding encrypted information and should not be readily accessed by unauthorized users. Production data should be backup regularly and off-site backup media should be kept in a secure location.
- *Application Security*: To protect the BEAP from malicious users, the following security principles will be applied to the implementation stage:
    - *Least privilege*: Ensure that applications are designed to run with the least amount of system privileges necessary to perform their tasks.
    - *Segregation of duties*: Ensure that the practice of segregation of duties is followed in such a way that critical functions are divided into steps among different individuals to prevent a single individual from subverting a critical process.
    - *Proper authentication and authorization*: Ensure that proper access control is enforced to restrict the privileges and access rights of the users.
    - *Proper session management*: Ensure that applications have proper and secured session management to protect the sessions from unauthorized access, modification or hijacking. Protection measures include generating unpredictable session identifiers, securing the communication channel, limiting the session lifetime, encrypting sensitive session contents, applying appropriate logout function and idle session timeout, and filtering invalid sessions.
    - *Input validation*: Ensure that strict validation is applied to all input of the application whenever the source is outside trust boundary such that any unexpected input, e.g. overly long input, incorrect data type, unexpected negative values or date range, unexpected characters such as those used by the application for bounding character string input, etc., are handled properly and would not become a means for an attack against the application.
    - *Proper error handling*: Ensure that the application will provide meaningful error message that is helpful to the user or the support staff yet ensuring that no sensitive information will be disclosed. Ensure that errors are detected, reported, and handled properly.

5.1.4.35 In physical level, all BEAP servers and equipment should be protected from unauthorized access. In logical level, the BEAP should ensure that the access rights are granted on a need-to-know basis and are clearly defined and documented. Proper user authentication, data and functionality authorization should be defined

in the BEAP by providing a unique user account for each B/Ds user to access the system. When B/Ds' users access the web portal, the users should have to enter the username and password for logon processing. After successful logon to the BEAP, relevant access rights of web apps, data and map services will be granted to the users based on their user roles.

5.1.4.36 In future, the functionality and services of various applications delivered to public should be limited and ensure no classified data is included. Password for authentication should be well protected by encryption when stored in the database and transmitted over untrusted network. Besides, good password rules (e.g. pre-defined limit on the length) should be enforced to avoid vulnerabilities. Audit log of the BEAP should be enabled and reviewed periodically so as to identify any sign of intrusion.

5.2 Operating Model and Governance

5.2.1.1 Based on the experiences of overseas cities such as Singapore and Portland, United States, it is recommended that a dedicated team supported by the staff with relevant expertise should be established to ensure a smooth operation and management of the BEAP. The successful experiences of many overseas cities have demonstrated how a small team of experts can function very efficiently in delivering specialist applications and in supporting users in their adoption.

5.2.1.2 Non-core functions should be divested so that the team can concentrate on the common applications with benefits to the users. Infrastructure provision and management, for example, could be hosted on the GovCloud. Access to relevant data can be routed through the CSDI which will focus on working with relevant B/Ds and data producers to streamline the provision of high quality data.

5.2.1.3 In the course of setting up the BEAP involving development of the supporting platform and initial applications, it is envisaged that some third party application developers and system integrators will be engaged to reduce the required time to build up the BEAP. Afterwards, the dedicated BEAP team would be responsible for subsequent upkeep of the database and maintenance of various built environment applications as well as the scale-up development.

5.2.1.4 It will be important for the BEAP Team to manage the knowledge of how the underlying platform works and how it operates. It is considered necessary to grasp the technical understanding of how the platform is constructed in order to maintain the software and further evolve the capabilities of the platform over time. The team should also manage the technical administration such as software upgrades and backups, and the technical support of the platform such as publishing new applications and trouble shooting and resolving issues. By taking responsibility for maintaining this knowledge in-house, the team will be able to react quickly and flexibly to change demands.

5.2.1.5 It is further recommended that the BEAP follow a collaborative approach in which its dedicated team of domain specialists would be supported by partners from the business, academia and indeed the public, who could in turn develop applications and/or actionable data for use within the BEAP platform and/or which may also be published via the BEAP. It will be important to develop awareness of the BEAP among the relevant communities and to maintain communication and outreach to regularly engage users and developers, and to maintain their involvement over time.

Proposed Staffing of the BEAP Team

5.2.1.6 In view of the above, subject to the leadership and governance of the CSDI, the BEAP will require a dedicated team to steer direction of BEAP planning and design, deliver the services, manage the platform and develop the applications. It is recommended to set up a BEAP team in PlanD to oversee and steer the development and operation of the BEAP. The responsibilities of the team would cover the following (**Figure 5.3**):

- **Platform and Applications Development**
    - Steer the development and enhancement of platform, applications and related services
    - Review and enhance the design and production processes
    - Create and update new function of applications hosted in BEAP
    - Create and produce actionable data (information products), which are mainly sourced from the CSDI, to support the needs of built environment applications
    - Update and create new actionable data entry provided by applications
    - Review and continuously improve the data exchange mechanism with CSDI
- **System and Technical Administration**
    - Support BEAP contractors to liaise with relevant internal and external parties (e.g. CSDI, OGCIO, B/Ds, etc.) to resolve issues regarding both platform and applications development
    - Coordinate and maintain the system of BEAP to ensure smooth running of the BEAP hardware and software infrastructure
    - Coordinate with different maintenance parties to carry out the maintenance tasks, and manage the resources required
    - Manage procurement and contract management of contractors

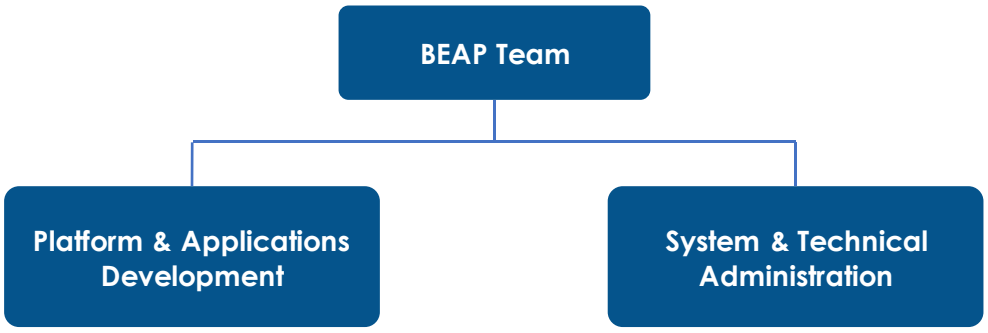


Figure 5.3 – Proposed Responsibilities of the BEAP Team

5.2.1.7 The BEAP Team should also be supported by PlanD internal Information Technology Management Unit colleagues and external consultants and software vendors in all different stages to design and build the platform, as well as develop

initial applications. Given that the BEAP is one of the core components of the CSDI Development Strategy being formulated by DEVB, subject to the Administration's steer, the BEAP team may ultimately be subsumed into the future CSDI governance structure. In addition, BEAP team will communicate with users and stakeholders, as well as academia to foster collaboration on the use and development of various applications, and in wider context extending to the business and the general public. Close liaison with the Capacity Building and Promotion Working Group (CBPWG) chaired by DEVB will be maintained on the engagement activities to reach out the relevant parties for promoting the BEAP.

5.2.1.8 It is also suggested that under this collaborative model, responsibility for the maintenance and upkeep of the applications hosted by the BEAP is held by the developer of the application. For example, BEAP-developed applications would be responsible by the BEAP team, while other applications to be developed by partner organisations (such as an academic institution) would be under the custody and management of these organisations.

5.3 Resources Estimation for Setting Up the BEAP

5.3.1 Implementation Cost of Overseas Case Studies

5.3.1.1 In Stage 1, the high-level cost estimation of Total Cost of Ownership (TCO)* from overseas case studies has been reviewed, which are summarised as below in **Table 5.4**.

Platform Adopted in Overseas Countries	Total Cost	Years of Operation	Annual Average Cost
AURIN (Australia)	HK$139.2M (AUD$24M)	8	HK$17.4M (AUD$3M)
Virtual Singapore (Singapore)	HK$420.5M (SGD$73M)	6	HK$70.1M (SGD$12.2M)
CGIS (Portland)	HK$141.2M (USD$18M)	7	HK$20.2M (USD$2.57M)

*Remark: Total Cost of Ownership includes all the cost of both the responsible party/government body and its contractor to design, build and operate the platform.

Table 5.4 – Annual Average Costs of Total Cost of Ownership for Overseas Case Studies

5.3.1.2 It should be noted that the development cost of the Virtual Singapore is much higher than other two models mainly because more resources have been put in developing various applications.

5.3.1.3 The cost of future development of the BEAP including hardware, software, implementation services, maintenance services and contingency, would be all depending on the number of applications, involved parties and users in the years to come.

5.3.1.4 With reference to the implementation cost of the overseas case studies, the initial few years are front-loaded with development costs and the ongoing annual operating costs are likely to be lower once the platform is in full operation in long term. This is dependent, of course, upon a stable operation. Should there be significant demand for the BEAP services and/or applications, then costs on implementation services, software development, etc. would rise commensurate with the increase in demand.

5.3.2 Cost for Platform Development of BEAP

5.3.2.1 Having investigated the implementation costs of the overseas case studies, the cost for the implementation of future BEAP would make reference to the funding and cost estimate of overseas experiences in conjunction with the local situation.

5.3.2.2 The cost estimation of the hardware, software as well as development and O&M for setting up of the BEAP is based on the following assumptions:

- The cost estimation of hardware refers to the services costs of data storage, CPU, memory, VMs, etc. for cloud services provider. System upgrade with higher requirements in hardware is assumed in the second year during the mid to long term development
- The cost estimate of software refers to the GIS-based and BIM-based software, other software provided by the cloud service provider (i.e. OGCIO GovCloud) are not included; It also assumes that the software are upgraded in the second and the fourth year during the mid to long term development
- The cost estimate of development and O&M refers to the following works carried out by the platform contractor based on the functional and technical requirements:
    - System Analysis and Design (SA&D)
        - Develop functional requirements and conduct detailed system design
        - Prepare system specification
        - Identify corresponding / additional hardware, software and any facilities / services corresponding to the system design, and make recommendation of technical requirements by taking into the current state of technology
        - Prepare the SA&D report
        - Consult and liaise with B/Ds and any relevant parties
    - System Implementation and Integration
        - Establish linkages with CSDI and other data platform
        - Set out procurement and implementation plan
        - Convert and process collected data
        - Establish rules for system and application integration
        - Develop various levels of test plans and test cases

- Conduct UAT
- Consult and liaise with B/Ds and any relevant parties

- System Installation and Production
  - Arrange and conduct training for the BEAP in-house staff
  - Prepare system handover documentation and maintenance plan
  - Conduct a disaster recovery drill before system live run according to the disaster recovery plan and procedures
- System Operation
  - Conduct system nursing and tuning
  - Conduct system handover

5.3.2.3 OGCIO is now implementing the big data analytics platform, which is targeted to be launched in 2020. This platform would provide underlying server, storage and network resources to expedite system development of e-government services and the implementation of more big data analytics projects with the adoption of big data analytics and AI technologies. Subject to further investigation, it may be possible to ride on this platform to develop the future BEAP to enable better resource utilisation.

5.3.3 Cost for Application Development of BEAP

5.3.3.1 As for the cost for development of the applications, it would very much depend on the development complexity (i.e. advancement in current technology, availability of the required software and hardware, functionality, customisation efforts, data readiness, etc.), which would be further investigated during the implementation stage. With due regard to the prototype development process, the development complexity of the 10 applications can be categorised into three levels (i.e. low, medium and high).

5.3.3.2 Cost for the contractor of each application development includes:

- Prepare SA&D
  - Develop data requirements, functional requirements and conduct detailed system design
  - Prepare system specification
  - Prepare the SA&D report
  - Consult and liaise with B/Ds and any relevant parties
- System Implementation and Integration
  - Establish linkages with CSDI and other data platform
  - Convert and process collected data
  - Liaise with platform contractor and configure application to the platform
  - Develop various levels of test plans and test cases

- Conduct UAT

- System Installation and Production
  - Arrange and conduct training for BEAP in-house staff
  - Prepare system handover documentation and maintenance plan
  - Conduct a disaster recovery drill before system live run according to the disaster recovery plan and procedures
- System Operation
  - Conduct system nursing and tuning
  - Conduct system handover

5.3.3.3 In general, around 18-24 months would be required to develop the application in the category of the low to medium complexity into an up-and-running system while longer time, say 24-30 months for the application of the medium to high complexity (**Table 5.5**).

Application	Complexity
Short Term (Quick-Win Projects)	
GIC Facilities and Open Space Analysis	L-M
Visualization and Analysis of Urban Green Infrastructure	M-H
Site Search	L-M
Mid to Long Term	
Landuse Monitoring and Analytics	H
Scenario Generation for Planning and Development	M-H
Compliance Checking of Building Plans	H
Visualization and Analysis of Underground Space and Utilities	H
Connectivity Analysis	M-H
Workflow Management Platform	L
Built Environment Information Dashboard	L

Table 5.5 – **Complexity Levels of Different Applications**

6 CONCLUSION

6.1 Conclusion

6.1.1.1 The BEAP has great potential to be further developed as the collaborative platform for Government, business, academia and research institutes to foster interdepartmental and multilateral co-operation, as well as to serve as a foundation of various types of spatially and digitally enabled built environment applications for planning and design formulation, decision making, resource management, statistical analysis as well as the delivery of high quality services to the public. Through the application development, the BEAP would also enhance innovation, knowledge and value creation for different segments of the populace starting from within the Government in the years to come.

6.1.1.2 It is crucial to make the BEAP available and to realize the benefits in short term along with the implementation timeline of CSDI, so as to maximize synergy, and to ensure that both platforms can be mutually beneficial to and interfaced well with each other. To secure a quick win in short term, the followings are the key enabling steps and factors:

- Policy mandate and support to sustain the momentum of the BEAP development at both platform and application levels after this consultancy study;
- Sufficient funding that enables the BEAP to implement and to reach a state where it could demonstrate benefits and incentivises participation and collaboration; and
- An enabling institutional arrangement with support of BEAP team that steers and drives development, procurement and reviews progress.

6.1.1.3 In summary, it is envisioned that this Study is able to provide a strategic guideline for the continuous development of the BEAP in the years to come.

6.1.2 Ultimate Form of BEAP

6.1.2.1 The development of the BEAP and its applications is a timely and strategically important initiative under CSDI initiative as Hong Kong embarks on its journey to become a livable, competitive, innovative, sustainable and smart city.

6.1.2.2 This initiative will have the ability to support the long term vision of Hong Kong as a smart city through the provision of a critical information infrastructure.

6.1.2.3 As demonstrated in the findings of this Study, the benefits reaped from the development of spatial data and application platform are not limited to various internal savings alone. This also includes improved service delivery and policy outcomes, which in turn lead to the realization of wider societal and economic benefits. Whilst societal and economic benefits may take time to materialize, they have been found to be of high order of magnitude when compared with benefits arising from internal savings.

6.1.2.4 To enable Hong Kong to realize the benefits of the CSDI in the long term, it will be key for the Government to ensure that the following key success factors are addressed:

- High level support and policy mandate to sustain the momentum of development;
- An enabling institutional arrangement that steers development and reviews progress;
- A sustainable source of funding that enables the CSDI to reach a state where it could demonstrate benefits and incentivize participation and collaboration; and
- A supportive eco-system whereby the Government, businesses, academic and the wider community are spatially knowledgeable in tapping on the potential of the CSDI.

Appendix A

Appendix A –Data Required for Development of Prototype Applications

Appendix A – Data Required for Development of Prototype Applications

	Prototype Application	Data Required																									
		AFCD					AMO			BD		C&SD		CEDD			DSD	HAD	HD		HyD	LandsD						
		Country Park	Fung Shui Woodland	Geopark	Ramsar Site	Special Area	Declared Monuments	Graded Buildings	Site of Archaeological Interest	Building Basement and foundation Piles	Building Regulations and Guidelines	Population Data	Population Projection	Air Raid Tunnel	LiDAR	Slope Information	Sewage and Drainage Mains of Selected Areas	District Council Boundary	Public Rental Housing Standard Block Layout	Sample Public Housing Project	Excavation plans and extents from XPMS	3D Pedestrian Network Model	3D Spatial Data	DOP5000 Digital Orthophoto	GeoCommunity Database	iB1000, iB5000, iB10000, iB20000 Digital Topographic Map	iC1000 Digital Land Boundary	iG1000 GeoReference Data
	Territory Level (T) or Project Level (P)	T	T	T	T	T	T	T	T	P	T	T	T	P	T	T	P	T	T	P	P	P	T	T	T	T	T	T
	Data Type	E	E	E	E	E	E	E	E	U	P	D	D	U	C	C	U	P	P	P	U	R	C	C	C	C	C	C
1	Landuse Monitoring and Analytics														✔									✔		✔		
2	Site Search	✔	✔	✔	✔	✔	✔	✔	✔						✔	✔							✔	✔		✔	✔	✔
3	Scenario Generation for Planning and Development										✔				✔				✔				✔	✔		✔		
4	GIC Facilities and Open Space Analysis											✔	✔		✔									✔		✔		
5	Connectivity Analysis														✔							✔	✔	✔	✔	✔		✔
6	Visualization and Analysis of Underground Space and Utilities									✔				✔	✔		✔				✔		✔	✔		✔		
7	Compliance Checking of Building Plans										✔									✔				✔		✔		
8	Visualization and Analysis of Urban Green Infrastructure														✔								✔	✔		✔		
9	Workflow Management Platform																						✔	✔		✔		
10	Built Environment Information Dashboard	✔										✔	✔		✔			✔						✔		✔		

Data Type:

P: Planning Context (P)

C: Cadastral and Topographical Context (C)

E: Environmental Context (E)

D: Demographic Context (D)

R: Road and Transport Context (R)

U: Utilities Context (U)

	Prototype Application	Data Required																					
		PlanD																					
		3D Photorealistic Mesh Model	Approved S.16 Applications, zoning amendments and Enforcement Cases	Brownfield Polygon	Brownfield Site Photos	Building Age	Closed Area Boundary, Wetland Buffer Area, Wetland Conservation Area	Digital Orthophoto & Digital Surface Model	Facilities for the Elderly and schools	Hong Kong Planning Standard and Guidelines	HSK NDA Project Information	Information from Pilot Study on Underground Space Development in Selected Strategic Urban Areas	Land Utilization MapS	Open Space and GIC Information	Outline Zoning Plan	Population Distribution Projections by WGPD	Potential Hazard Installation	Residential, Industrial, Commercial and Hotel Land Uses	Sample Study Briefs / Tender Documents	Satellite Images	Site of Special Scientific Interest	Statutory Planning Scheme Boundary	Territorial Population and Employment Data Matrix (TPEDM)	Tertiary Planning Units, Street Block/ Village Cluster and New Town Boundary
	Territory Level (T) or Project Level (P)	T	P	P	P	T	T	P	T	T	P	P	T	T	T	T	T	T	P	T	T	T	T	T
	Data Type	C	P	E	E	C	P	P	P	P	P	P	C	P	P	D	P	P	P	C	P	P	D	P
1	Landuse Monitoring and Analytics			✔	✔			✔												✔				
2	Site Search	✔				✔	✔		✔			✔	✔	✔	✔		✔				✔	✔		
3	Scenario Generation for Planning and Development	✔								✔	✔				✔									
4	GIC Facilities and Open Space Analysis	✔							✔	✔				✔	✔	✔							✔	
5	Connectivity Analysis	✔													✔									
6	Visualization and Analysis of Underground Space and Utilities	✔										✔												
7	Compliance Checking of Building Plans		✔																					
8	Visualization and Analysis of Urban Green Infrastructure	✔													✔					✔				
9	Workflow Management Platform	✔																	✔					
10	Built Environment Information Dashboard					✔							✔	✔		✔		✔					✔	✔

Data Type:
P: Planning Context (P)
C: Cadastral and Topographical Context (C)
E: Environmental Context (E)
D: Demographic Context (D)
R: Road and Transport Context (R)
U: Utilities Context (U)

	Prototype Application	Data Required														Remarks
		TD	TMO	WSD		HKU	MTR		PolyU						UUs	
		Intelligent Road Network	Tree Information	Water Gathering Ground	Water Mains of Selected Area	Pedestrian Flow Prediction Model	MTR Stations	Railway Protection Zone	Anthropogenic Heat	Estimated Tree Biomass	Green Space Factor	Landuse Classification Map	Vegetation Cover	Vegetation Density	Electrical mains, Gas Pipes, Telecommunication Cables	
	Territory Level (T) or Project Level (P)	T	T	T	P	P	T	T	P	P	P	P	P	P	T	
	Data Type	R	E	E	U	R	R	R	E	E	E	E	E	E	U	
1	Landuse Monitoring and Analytics											✔				Site photos or other images can be collected from B/Ds if available to scale up resource library; PolyU processed Landuse Classification Map using satellite images and other relevant data
2	Site Search	✔		✔				✔								AFCD would be consulted on the better approach for use and the interpretation of data of the Fung Shui Woodland, Country Park, Ramsar Site, Geopark, Marine Park and Special Areas
3	Scenario Generation for Planning and Development	✔														
4	GIC Facilities and Open Space Analysis	✔														
5	Connectivity Analysis	✔	✔			✔										
6	Visualization and Analysis of Underground Space and Utilities				✔		✔	✔							✔	
7	Compliance Checking of Building Plans															A BIM model was built from a sample public housing project for testing in this prototype
8	Visualization and Analysis of Urban Green Infrastructure		✔						✔	✔	✔		✔	✔		PolyU processed the data of Vegetation Cover, Vegetation Density, Estimated Tree Biomass, Green Space Factor and Anthropogenic Heat using satellite images and other relevant data
9	Workflow Management Platform															
10	Built Environment Information Dashboard															AFCD would be consulted on the better approach for use and the interpretation of data of the Country Park and Special Area

*Advice and approval regarding the use of these data would be sought with relevant B/Ds during the implementation stage of the applications.

Data Type:
P: Planning Context (P)
C: Cadastral and Topographical Context (C)
E: Environmental Context (E)
D: Demographic Context (D)
R: Road and Transport Context (R)
U: Utilities Context (U)

Appendix B

Appendix B – Prioritization of Application Development

Appendix B – Prioritization of Application Development

	APPLICATION	Criteria																											Overall Scoring	Implementation Phasing
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29		
		Application Area / Topic				Fit with BEAP objectives					Acceptance & Ease of Use		Wider Benefit			Collaboration & Support from B/Ds		Data Readiness		Infrastructure & Support				Scalability								
		Fit with Thematic Area	Direct response to built environment issues	Sustainability & Environmental awareness	Resource Management	Fostering Cooperation between Govt., Academic, Industry	Enhancing Efficiency, Transparency, Support	Degree of support CSDI & Smart Initiatives	Degree of access to built environment	Degree of access to actionable data	Degree of simplicity in operation	Amount of training required	Effect on public interests	Effect on public accessibility to data	Degree of public communication	Degree of B/D Data contribution	Degree of deployment for wider B/D use	Availability of data	Technology maturity	Demand for IT (communication) infrastructure	Need for hardware support	Need for software support	Backwards compatibility	Functional	Data	Spatial Coverage	User base	Adoption of New Technology	Facilitate Implementation of Development Projects	Interdependency between application		
1	Landuse Monitoring & Analytics	H	H	H	H	M	M	H	H	M	H	M	M	M	M	H	M	M	M	M	H	M	H	L	M	H	L	H	M	M	M	**Mid-Long (Batch 1)**
2	Site Search	H	H	H	H	M	M	H	H	H	H	M	L	L	L	L	H	H	H	H	H	M	H	H	H	H	M	M	H	H	H	**Short Term**
3	Scenario Generation for Planning and Development	H	H	H	H	M	H	H	M	M	M	M	L	L	L	M	H	H	M	M	H	M	M	M	H	H	M	H	H	H	M	**Mid-Long (Batch 1)**
4	GIC Facilities and Open Space Analysis	H	H	H	H	M	H	H	H	H	H	H	H	H	H	L	H	M	H	M	H	M	H	H	H	H	H	L	H	H	H	**Short Term**
5	Connectivity Analysis	H	H	M	M	L	M	M	L	L	L	L	M	L	L	M	M	L	L	L	H	M	M	M	L	H	L	M	M	H	L	**Mid-Long (Batch 2)**
6	Visualisation and Analysis of Underground Space and Utilities	H	H	M	H	M	H	M	M	L	L	M	L	L	M	M	M	L	M	L	H	M	M	L	L	H	L	M	M	H	L	**Mid-Long (Batch 2)**
7	Compliance Checking of Building Plans	H	H	H	H	H	H	H	M	M	M	M	L	L	L	M	H	H	M	M	H	M	H	L	M	H	L	M	H	M	M	**Mid-Long (Batch 1)**
8	Visualisation and Analysis of Urban Green Infrastructure	H	H	H	H	M	M	H	H	H	H	H	H	H	H	M	H	M	H	M	H	M	H	H	H	H	H	L	H	M	H	**Short Term**
9	Built Environment Information Dashboard	M	M	M	L	L	M	M	L	L	H	H	H	H	M	L	M	L	M	L	H	M	H	H	H	H	H	L	L	L	L	**Mid-Long (Batch 2)**
10	Workflow Management	H	M	H	M	M	H	L	L	L	L	M	L	L	L	H	H	H	M	M	H	M	M	L	M	H	L	H	M	L	L	**Mid-Long (Batch 2)**

L: Low
M: Medium
H: High