International Telecommunication Union

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

L.1610

(08/2022)

SERIES L: ENVIRONMENT AND ICTS, CLIMATE CHANGE, E-WASTE, ENERGY EFFICIENCY; CONSTRUCTION, INSTALLATION AND PROTECTION OF CABLES AND OTHER ELEMENTS OF OUTSIDE PLANT

Circular and sustainable cities and communities

City science application framework

Recommendation ITU-T L.1610

ITU-T L-SERIES RECOMMENDATIONS

ENVIRONMENT AND ICTS, CLIMATE CHANGE, E-WASTE, ENERGY EFFICIENCY; CONSTRUCTION, INSTALLATION AND PROTECTION OF CABLES AND OTHER ELEMENTS OF OUTSIDE PLANT

OPTICAL FIBRE CABLES	
Cable structure and characteristics	L.100–L.124
Cable evaluation	L.125–L.149
Guidance and installation technique	L.150–L.199
OPTICAL INFRASTRUCTURES	
Infrastructure including node elements (except cables)	L.200–L.249
General aspects and network design	L.250–L.299
MAINTENANCE AND OPERATION	
Optical fibre cable maintenance	L.300–L.329
Infrastructure maintenance	L.330–L.349
Operation support and infrastructure management	L.350–L.379
Disaster management	L.380–L.399
PASSIVE OPTICAL DEVICES	L.400–L.429
MARINIZED TERRESTRIAL CABLES	L.430–L.449
E-WASTE AND CIRCULAR ECONOMY	L.1000–L.1199
POWER FEEDING AND ENERGY STORAGE	L.1200–L.1299
ENERGY EFFICIENCY, SMART ENERGY AND GREEN DATA CENTRES	L.1300–L.1399
ASSESSMENT METHODOLOGIES OF ICTS AND CO2 TRAJECTORIES	L.1400–L.1499
ADAPTATION TO CLIMATE CHANGE	L.1500–L.1599
CIRCULAR AND SUSTAINABLE CITIES AND COMMUNITIES	**L.1600–L.1699**
LOW COST SUSTAINABLE INFRASTRUCTURE	L.1700–L.1799

For further details, please refer to the list of ITU-T Recommendations.

Recommendation ITU-T L.1610

City science application framework

Summary

Recommendation ITU-T L.1610 proposes to analyse and solve urban problems and challenges by using the city science method. It demonstrates that by using empirical evidence such as data, the city science method provides the most reliable and consistent way for cities to tackle urban challenges.

As urbanization continues to accelerate, urban governance is struggling to adapt to environmental and sustainability challenges. The high degree of urban sprawl demands urban planning to be reinvented in order to improve land and resource allocations. This creates further tension between urban and suburban areas (locations of close proximity to cities) in terms of economic and environmental sustainability.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T L.1610	2022-08-13	5	11.1002/1000/15033

Keywords

Application framework, cities, sustainability.

* To access the Recommendation, type the URL http://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID. For example, http://handle.itu.int/11.1002/1000/11830-en.

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications, information and communication technologies (ICTs). The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

Compliance with this Recommendation is voluntary. However, the Recommendation may contain certain mandatory provisions (to ensure, e.g., interoperability or applicability) and compliance with the Recommendation is achieved when all of these mandatory provisions are met. The words "shall" or some other obligatory language such as "must" and the negative equivalents are used to express requirements. The use of such words does not suggest that compliance with the Recommendation is required of any party.

INTELLECTUAL PROPERTY RIGHTS

ITU draws attention to the possibility that the practice or implementation of this Recommendation may involve the use of a claimed Intellectual Property Right. ITU takes no position concerning the evidence, validity or applicability of claimed Intellectual Property Rights, whether asserted by ITU members or others outside of the Recommendation development process.

As of the date of approval of this Recommendation, ITU had not received notice of intellectual property, protected by patents/software copyrights, which may be required to implement this Recommendation. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the appropriate ITU-T databases available via the ITU-T website at http://www.itu.int/ITU-T/ipr/.

Table of Contents

Introduction

Urbanization is progressing at an unprecedented rate with 68% of the world population expected to reside in urban areas by 2050 [b-UN]. 90% Of the increase in world population is expected to take place in Asia and Africa, putting tremendous pressure on these regions to cope with the new human development challenges associated with this influx of population. It is important to acknowledge that while urban migration brings new economic opportunities and makes social services and cultural activities more accessible to many, it is equally important to address the rising challenges that urban governance has to address, including economic inclusiveness, increased resource consumption, environmental deterioration, surging housing needs and new physical infrastructure.

This high degree of urban sprawl demands urban planning to be reinvented in order to improve land and resource allocations. This creates further tension between urban and suburban areas (locations of close proximity to cities) in terms of economic and environmental sustainability. Mobility is becoming one of the most significant concerns for city inhabitants all over the world as the associated economic and health costs are ever rising. The lack of affordable housing with basic necessities, such as, water, energy, sanitation and waste disposal, causes informal settlements that often fail to comply with basic planning and regulations to flourish. The pressure on food, water and energy resources is also steadily mounting.

Urban sprawl also adversely impacts urban environment by diminishing green spaces, intensifying air pollution and increasing waste generation. Furthermore, cities are dense and highly congested places that are prone to the devastating consequences of climate change. More than 80% of cities in 2014 were located in areas that are vulnerable to economic losses associated with natural disasters and other environmental catastrophes [b-IPCC]. Sea level rise, floods, storms, urban heat wave, earthquakes, etc. are all potential resilience challenges that urban areas have to confront.

In this context, this Recommendation uses a scientific method, the city science method, to analyse and solve these urban problems and challenges. It demonstrates that by using empirical evidence such as data, the city science method provides the most reliable and consistent way for cities to tackle urban challenges.

Recommendation ITU-T L.1610

City science application framework

1 Scope

This Recommendation provides a framework for using scientific techniques and data-driven methods to solve urban challenges including environment and sustainability. This framework consists of a four-step methodology that enables city stakeholders to use empirical evidence to assess, prioritize and boost their city applications. This framework first defines the core components of the city science application framework, including data, scientific techniques, the role of city science stakeholders and city science enablers. It then details the four-step methodology for implementing science solutions and assessing their projected impacts, including:

1) assessment of the current city science applications status (baselining);
2) identification of the prioritized areas to apply city science;
3) boosting city science applications using enablers;
4) assessment of projected city science applications impact.

The city science application framework provides a practical approach to solve urban challenges and is expected to support city stakeholders to achieve the Sustainable Development Goals.

This Recommendation is based on [b-U4SSC F].

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

None.

3 Definitions

3.1 Terms defined elsewhere

None.

3.2 Terms defined in this Recommendation

None.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AI	Artificial Intelligence
ICT	Information and Communication Technology
IoT	Internet of Things
NGO	Non-Governmental Organization
PESTEL	Political, Economic, Social, Technological, Environmental and Legal

PPP Public–Private Partnership

R&D Research and Development

5 Conventions

None.

6 City science

City science is the use of scientific methods and techniques to solve urban problems and challenges. The scope of problems addressed by city science encompasses a wide range of sectors. In this Recommendation, city science:

- aims to address and solve urban challenges and problems;
- uses data extensively;
- applies scientific techniques and methods by using science, technology and innovation.

The following simple steps describe the city science approach, formulated in this Recommendation, to solve a given urban problem.

- Identification – entails understanding the urban problem.
- Modelling – includes transformation of the identified urban problem into a model that represents it.
- Model solution – entails derivation of a solution to the initially identified urban problem.
- Model application – includes the actual implementation of a city science solution in the context of a real city by applying the model solution to the urban problem. It may also entail applying a set of enablers to accelerate and increase the likelihood of success.

Clause 9 introduces a city science application methodology that incorporates these steps among others into the overall framework.

6.1 Urban challenges and problems

The following is a list of potential urban problems sorted into different categories as identified in this Recommendation:

a) environment (air, water, energy, land, waste, biodiversity, green spaces, etc.);

b) mobility (transportation, movement, traffic, etc.);

c) economy (financial sectors and industries, etc.);

d) society (people, education, health, etc.);

e) governance;

f) safety and security;

g) resilience.

Urban problems in these categories create enormous opportunities for the application of city science.

6.2 Data

Cities today have a large number of data sources. Digital transformation and information and communication technology (ICT) initiatives in the landscape of emerging technologies have proliferated data creation and consumption in cities. Edge devices, Internet of things (IoT), city information systems, legacy systems, etc., generate a huge amount of data. In this context, data acts as a strategic asset for cities through which they can generate new insights, create new services and resolve various urban challenges.

City science utilizes city data as input or raw material to solve urban challenges. The potential of data is enormous when transformed into beneficial insight and action by the city.

6.3 Scientific techniques and methods

City science uses scientific techniques and other data driven methods to solve urban challenges. The dynamic and complex nature of cities allows mathematical models and techniques to be applied; i.e., urban problems can be modelled and recast as scientific models and problems.

The complex behaviours and relationships within and between different city constituents form various flows and networks. Modelling such phenomena is conducive to application of sophisticated analysis and problem-solving techniques such as optimization, stochastic and deterministic models, simulation, bottom-up evolutionary models, graphs and networks and mathematical programming techniques (linear and dynamic).

7 City science stakeholders

Components of the circular city implementation framework

There is a broad range of stakeholders for city science. Urban problems and their solutions exist in a rich ecosystem composed of many organizations that contribute directly or indirectly. The consumers, providers and beneficiaries of city science solutions encompass a multitude of entities or organizations in general.

The ecosystem for solving urban problems through the application of city science includes the stakeholders listed in Table 1, among potential others.

Table 1 – Existing definitions of circular economy

City science stakeholder type	Stakeholder brief description and relationship to city science
Public sector	The public sector is the part of an economy in which goods and services are produced and/or (re)distributed by government [b-US Legal 2]. Hence, it includes public services and public enterprises. Public services include public goods and governmental services such as the public infrastructure (public roads, bridges, tunnels, water supply, sewers, electrical grids, telecommunications, etc.), public transit, public education, along with health care, military, police. Public enterprises, or state-owned enterprises, are self-financing commercial enterprises that are under public ownership which provide various private goods and services for sale and usually operate on a commercial basis [b-QHSE]. Public sector organizations can utilize city science in enhancing public services and increasing their effectiveness and efficiencies (e.g., public services planning, energy and water efficiency, transportation routes optimization, traffic flow enhancement and air quality enhancement).
Private sector	The private sector is the part of an economy in which goods and services are produced and distributed by individuals and organizations that are not part of the government or state bureaucracy [b-US Legal 1]. The private sector is run by private individuals or groups, usually as a means of enterprise for profit, and is not controlled by the state. Private sector can take a producer (supplier) role of city science solutions and services. Urban problems form a viable and potential commercialization opportunity for the private sector.
City manager (administrator)	A city manager is an official appointed as the administrative manager of a city, in a council-manager form of city government. Local officials serving

Table 1 – Existing definitions of circular economy

City science stakeholder type	Stakeholder brief description and relationship to city science
	in this position are sometimes referred to as the chief executive officer or chief administrative officer in some municipalities [b-WCM]. City managers have a major stake in terms of finding solutions to their urban problems and challenges. City science can be used as a tool by city managers for addressing their urban challenges.
Academia (higher education)	Academia refers to the worldwide professionals composed of professors and researchers at institutes of higher learning [b-WA]. Academia plays a major role in enhancing and developing the city science human capital both in terms of numbers and also in terms of knowledge and expertise.
Chambers of commerce	A chamber of commerce is an association or network of businesspeople designed to promote and protect the interests of its members. A chamber of commerce, also known as a board of trade, is often made up of a group of business owners that share a locale or interests but can also be international in scope. They will choose leadership, name representatives and debate which policies to espouse and promote [b-ICC]. Hence chambers of commerce can play a federating role for private sector as a focal point for city science solutions.
Trade associations (sector bodies, etc.)	A trade association, also known as an industry trade group, business association, sector association or industry body, is an organization founded and funded by businesses that operate in a specific industry. An industry trade association participates in public relations activities such as advertising, education, political donations, lobbying and publishing, but its focus is collaboration between companies. Associations may offer city science-related services, such as producing conferences, networking or charitable events or offering classes or educational materials. They can also represent the interests and viewpoints of city science solution providers.
Non-governmental organization (NGO)	NGOs are usually non-profit and sometimes international organizations independent of governments and international governmental organizations (though often funded by governments) that are active in humanitarian, educational, health care, public policy, social, human rights, environmental, and other areas to affect changes according to their objectives [b-WNGO]. NGOs can promote city science and convey their perspectives and objectives related to city science and its development.
Data scientist	Data scientists are professionals who use scientific methods, processes, algorithms and systems to extract knowledge and insights from data in various forms, both structured and unstructured [b-WDS]. Data scientists play a critical role in implementing city science solutions. They can assist in modelling and solving urban challenges.
Utility supplier	Public or private sector organizations that supply communities with services for electricity, gas, water and sewerage, etc. These suppliers can play the role of demand creators for city science solutions related to their services. City science solutions can enhance quality availability efficiency, etc., of services.

Table 1 – Existing definitions of circular economy

City science stakeholder type	Stakeholder brief description and relationship to city science
Open data provider	Public and private sector organizations that provide open data, which is data that can be freely used, re-used and redistributed by anyone – subject only, at most, to the requirement to attribute and share alike [b-ODH]. Open data providers can supply the data required for city science solutions to address urban challenges.
Other data provider (shared, private data, e.g., data marketplaces)	Public and private sector organizations that provide data other than open data. Similar to open data providers, they can supply the data required for city science solutions to address urban challenges.
Data-processing and management personnel	City personnel with data processing and management skills are potential stakeholders for the application of city science to solve urban problems. Such personnel participate in all economic activities related to city science solutions, pertinent data processing and management, etc.
Data regulatory agency	A data regulatory agency, authority or body or a regulator is a public authority or government agency responsible for exercising autonomous authority over data in a regulatory or supervisory capacity. An independent data regulatory agency is independent of other branches or arms of the government. Data regulations shape and impact city science solutions in terms of how they use, process and manipulate data to ensure compliance with applicable regulations.
Data standards development organization (SDO)	An SDO, or data standards setting organization (SSO) is an organization whose primary activities are developing, coordinating, promulgating, revising, amending, reissuing, interpreting, or otherwise producing data technical standards that are intended to address the needs of a group of affected adopters [b-FIDO Alliance]. City science solutions can ensure compliance with commonly agreed standards by utilizing them in implementations.
ICT infrastructure/service provider	Encompasses all providers of infrastructure and services related to ICTs. These providers can support and supply data-related activities and services. They can provide readily available connectivity, data processing and security solutions, etc., to accelerate the implementation of city solutions.

8 City science enablers

A non-exhaustive list follows of enablers (potential policy tools and levers) that a city can use to assess, implement, and boost city science.

i *Raising awareness – communicating and educating various stakeholders such as public and policy makers as well as academia*: City science is a new field and awareness, which can be considered as an introduction to informed action, is limited. Awareness focuses on the general knowledge of city science as a new field as it progresses globally. Targeted awareness activities should provide stakeholders with relevant information about city science. Awareness activities can emphasize the specific roles and contributions of stakeholders in enhancing city science. It can also be extended to public awareness, which helps selected individuals understand and drive other individuals to participate effectively in activities establishing and developing city science. The benefits can be explained to stakeholders. which will increase the likelihood of adoption of city science methods and solutions.

ii *Publishing materials for city science (such as articles, reports, publications)*: As part of creating and boosting expertise in city science, existing knowledge can be disseminated. Articles, papers, on-going research, reports and miscellaneous publications can be shared among practitioners, willing contributors and volunteers in cities. Such knowledge exchange catalyses adoption of city science and also accelerates knowledge creation.

iii *Enhancing skills and competencies*: City science entails human capital with a wide variety of skills and competencies with the ability to learn, adapt and retrain. Formal education is one primary means to enhance city science. Curricula emphasizing data skills, data science, etc. as well as general competences such as critical thinking, problem solving and innovation might be helpful. Universities, colleges and vocational training centres play an essential role. Given the incessant advances in city science as a new field, the acquisition of related expertise is a lifelong process; hence continuing education and ongoing skills development are of paramount importance. Professional and training programmes provided by various institutes, online courses, etc. are all part of lifelong learning for city science.

iv *Stakeholder engagement and participation*: It is important for cities to engage a wide range of stakeholders in city science and to ensure their participation and inclusivity throughout the process. Collaboration platforms can be used by cities to encourage public, private and academic engagement. Nurturing a strong and vibrant ecosystem will help boost city science. Entrepreneurs can be encouraged and incentivized to launch start-ups in city science addressing real urban problems. Similarly, NGOs and civil society can bring the perspectives of related organizations and society members to city science implementation. Consequently, it is important to establish stakeholder engagement platforms where stakeholders discuss and engage in city science-related activities (e.g., conferences, forums, consultations).

v *Public and private sector policies and strategies*: Public and private sector policies and strategies can help drive city science innovation in a mutually supportive manner. They can boost demand and supply of city science applications and solutions significantly. Real life implementations of policies and strategies, such as smart city and digital transformation, predominantly rely on data and city science solutions. Consequently, they create actual demand for city science solutions in alignment with the objectives specified in such policies and strategies. The broad range of city science stakeholders described in this Recommendation indicates the need for a wide-reaching approach crossing boundaries of institutions, sectors, organizations, academic disciplines, etc. The differences in maturity level of cities with respect to city science may necessitate a tailored approach for strategies and policies. A unified vision along with supportive coherent strategies and policies can help cities adopt city science while addressing their particular urban issues, improving their economic performance and also addressing their specific social and environmental challenges.

vi *Research and development (R&D) programmes*: R&D expenditure by industries other than telecommunications has been critical in the emergence of innovation networks. R&D helps in building capabilities, tapping into clusters of new knowledge and bringing in highly talented workers for city development. Therefore, targeted R&D expenditures are important to develop innovative techniques and methods that are required in city science. Different urban challenges and city problems can also be analysed and turned into R&D requirements.

vii *Laws and regulations*: City administrations, or in some cases national governments, can issue laws and regulations that directly or indirectly impact city science. These may be embodied in legislation, regulations, compliance requirements, guidelines, etc. regarding city data, city science methods and algorithms (e.g., data protection, data privacy, data governance legislations, artificial intelligence (AI) ethical guidelines). These laws and regulations are important mechanisms to deal with issues related to city science and constitute an effective lever for enhancing adoption of city science.

viii *City science-related entrepreneurships and start-up support*: Enhancing city science skills and competencies and investing in R&D programmes create short- to long-term potential for boosting city science. However, businesses constitute the main means of converting city science ideas into wealth and jobs. In this context, entrepreneurs and start-ups play a critically important role in turning emerging technological and commercial opportunities into real businesses. Hence, policies that focus on fostering city science start-ups can be used as an enabler to cause city science to flourish.

Additionally, incubators and accelerators can help prepare city science businesses and start-ups for growth by providing guidance and mentorship in slightly different ways and at various stages in their lives.

Incubator programmes can assist city science businesses in their start-up phase by offering office space, business skills training, access to financing and professional networks, etc. Incubator programmes can help city science businesses to their feet in their start-up phase and may last for variable periods of time depending on business.

Incubators provide management guidance, technical assistance and consulting tailored to growth in city science businesses. They also provide clients with access to appropriate rental space and flexible leases, shared basic business services and equipment, technology support services and assistance in obtaining the financing necessary for growth [b-U4SSC C].

On the other hand, accelerator programmes can last for a certain period of time and aim to accelerate growth for city science companies rapidly (hence the name). They aim to help develop necessary skills for city science entrepreneurs through mentoring, formal training, informal peer learning, advice, etc. They target existing city science businesses and may potentially take a holistic advisory approach to enable rapid growth. See Table 2.

Table 2 – Key differences between incubators, investors and accelerators

	Incubators	**Angel investors**	**Accelerators**
Duration	1 to 5 years	Ongoing	3 months
Cohorts	No	No	Yes
Business model	Rent; non profit	Investment	Investment, can also be non-profit
Selection	Non-competitive	Competitive, ongoing	Competitive, cyclical
Venture	Early, or late	Early	Early
Stage education	*Ad hoc*, human resources, legal, etc.	None	Seminars
Mentorship	Minimal, tactical	As needed, by investor	Intense, by self and others
Venture location	On site	Off site	On site

Source: [b-Cohen].

ix *Financial incentives*: Access to finance and various other financial incentives can play a major role for city science start-ups and businesses. Financing city science innovation is inherently risky and may require a longer time horizon. Therefore, financing can be a potential barrier to market entry for entrepreneurs. Properly functioning venture capital markets and securitization of innovation-related assets can be important for city science start-ups. Easing access to debt and equity financing can provide incentives for city science start-ups and small businesses. Similarly, tax incentives can encourage city science entrepreneurs to start up their own businesses (exemptions and reductions, holidays, breaks, etc. from tax).

x *Demand side city challenges*: City managers and administrators can create real business opportunities for city science entrepreneurs and businesses by identifying real urban challenges and problems. As discussed in the introduction, cities globally are facing

significant challenges. These challenges can be recast as city science problems. City science businesses can create solutions for these challenges by harnessing data, algorithms, etc. Hence, actual demand in the form of real business opportunities has the potential to create a viable market for city science.

xi *Data driven problem identification*: In addition to city administrations defining their specific urban problems, city stakeholders can use actual city data (e.g., open data, city data provided by public or private sector organizations, citizen data) to identify and characterize urban challenges and problems. This is an alternative approach to city science innovation and related stakeholders can be engaged in a systematic manner, such as participating in a city science hackathon or challenge.

xii *Awards*: City science-related awards can be used as an incentive to recognize city science-related innovative products, services or outstanding individuals. Awards can encourage creativity and innovation in city science.

xiii *City as a laboratory*: An urban environment can theoretically be thought of as a laboratory, in the context of which city science solutions can be developed and implemented. Cities today create and collect enormous amounts of data while providing various functions and services for their inhabitants and constituents. Hence, the readily available actual city data can be processed and used for innovation, which practically can be considered as turning the city into a laboratory. City science solutions can be tested in real urban environments (akin to laboratory testing) and successful ones can be deployed to address real urban problems. Hence, some cities depict themselves as laboratories or open laboratories for innovation. Such an approach can incentivize city science solutions and applications.

xiv *Public–private partnerships for addressing urban problems*: Public–private partnerships (PPPs) can be utilized to complement the skills and assets of the public and private sectors in implementing city science solutions (e.g., Google Sidewalk Labs in Toronto, Smart Dubai Platform (see p. 97 of [b-U4SSC SDG]). A PPP enables partners to align and unify their goals and share risks and rewards for city science implementations. They can also complement each other's skills and resources for city science. Building a PPP is a relatively novel capability compared to traditional public procurement. It requires a sound understanding and modelling of risks and rewards. The missions and *raisons d'être* of public and private sector organizations tend to differ. Unifying a common city science vision and mission for partners is quite critical. A one size fits all framework does not exist for PPPs since they tend to vary in terms of arrangements based on city science implementation project (e.g., short- to medium-term management contracts, outsourcing arrangements, build-operate-transfer arrangements, joint ventures). The degree of ownership of assets and expenditures by partners also varies significantly depending on type of PPP. Hence, it is important to agree on a viable PPP model early on by partners and to address issues around it. On the other hand, PPPs provide significant advantages by bringing together the best of both worlds (public and private sector) with each contributing significantly to the partnership in city science. Innovative city science ideas can be jointly developed by partners by sharing investment, revenues and risks.

xv *Global data standards and data standardization*: City science solutions utilize city data extensively. Hence data standards can increase the efficiency of city science implementations, expedite solutions, and enable cost savings by capitalizing on them. For data, city science solutions can leverage existing standards for definitions, processing, exchange and interoperability were deemed feasible and available. Standards can provide a common language and common framework(s) for data processing and management in city science solutions.

xvi *Open-source city science applications*: Practitioners, volunteers and enthusiasts can provide open-source city science applications (software or algorithms) on a non-commercial basis. These open-source applications will be freely available to all interested cities and city science

solution providers to solve urban challenges. Open-source city science applications can provide advantages in terms of security, quality, customizability, flexibility, cost, etc. They can provide city science entrepreneurs and businesses with a solution that is already available for implementation; which can incentivize further innovation by enhancing and advancing existing city science applications. Open source also encourages sharing of city science applications among cities (as they are openly accessible).

xvii *Sharing city science solutions across cities and scaling them up*: Cities globally share common challenges and problems to a certain extent. Hence, the creation of platforms whereby solutions are shared and even enhanced based on the needs of real cities is very important in boosting city science. Usage (adoption) of city science solutions by several cities will expand the potential market opportunity for entrepreneurs and businesses. It will help in scaling up solutions and will also enable further R&D for them.

Cross-city collaboration for urban problem solving: Each city on its own may find it both commercially and operationally challenging to develop city science due to various restrictions (e.g., human capital, financing, market size). On the other hand, cross-city collaborations may amplify the magnitude of city science potential in terms of resources, market opportunities and portfolio of feasible solutions. Scaling up may render city science solutions feasible, which otherwise would not be so. Hence, cities can form multiple city collaborations and partnerships to boost city science while addressing their own challenges and creating real market opportunities for businesses. Bilateral or multilateral agreements and partnerships can be established to help city science develop locally, regionally and globally.

9 City science application framework – Methodology

This clause describes the four-step city science application framework methodology. The methodology specified in this clause is an action-oriented, pragmatic approach to solving city challenges that emphasizes strategy implementation:

1) assess current city science applications status (baselining);
2) prioritize and determine city science applications;
3) boost city science applications;
4) assess projected city science applications impact.

Clauses 9.1 to 9.4 briefly explain the four-step methodology to determine and implement city science solutions by cities and to assess their projected impacts.

9.1 Step 1: Assess the current city science applications status (baselining)

This step involves setting the baseline scenario for the application of city science by determining the solutions that are currently being undertaken by the city and the potential enablers that would support in implementing them. Specifically, this step determines a city's current status (baseline) with respect to:

a) the existing city science solutions and their applications; and
b) the existing enablers that would support the implementation of city science solutions.

Each of these two components are explained in clauses 9.1.1 and 9.1.2.

9.1.1 Implementation of city science solutions

This component determines the city science solutions that are being implemented by a city, which may have been undertaken as part of its overall approach to implementing smart city initiatives (e.g., pilots, trials and strategic projects) and may reflect its own particular urban needs. In some cases, they may be national level initiatives (e.g., Sustainable Development Goals – SDGs implementation) undertaken at the city or local level.

Most likely, there will be multiple city science solutions being implemented by a city.

Table 3 indicates a simple approach that a city can use to gather its city science solutions being implemented.

Table 3 – Details of city science solutions implemented by a city

City science solution No.	Brief explanation	Implementation milestones	Owner	Comments
City science solution 1				
City science solution 2				
… City science solution *N*				

9.1.2 City science enablers in place

City science enablers are described in clause 8. The presence and utilization of these enablers can potentially aid a city to implement its city science solutions.

Table A.1 simply lists these enablers. It can be used by a city to assess its current status or baseline with respect to its city science enablers. The questions in Table A.1 are fairly high level, and in some cases may require further clarification and description by the city to determine its current status.

9.2 Step 2: Prioritize and determine city science applications

A city can engage a broad range of stakeholders not only to describe its own city science priorities and needs, but also to determine a list of city science ideas for future implementation. Having assessed its current status in step 1, the city will be in a better position to formulate additional city science solutions in line with its priorities.

Broad stakeholder engagement can assist in identifying a comprehensive list of potential city science-related innovations. Specific needs and priorities may help emphasize certain city science solutions or conversely deemphasize or eliminate others. Each city may have to go through this exercise based on its own context and specific aspirations and goals.

Another important input to this step is the benchmarking of successful city science solutions in other cities. The city needs to be careful in assessing the applicability of international benchmarks as the context and particular aspects of other cities may vary significantly.

In this step, a long list of city science solutions can be formulated. In fact, it might be preferable for a city to utilize its collective capital extensively to come up with various ideas to address its own urban challenges.

The city may not be equipped for or lack the requisite resources to implement the list of city science ideas in its entirety. In such cases, a prioritization mechanism will be highly beneficial. A pragmatic prioritization approach is included in this city science application framework with two main criteria: i) the value that identifies the projected value of the city science idea; ii) identification of the projected ease of implementation of the city science idea in the particular context of the city. Each criterion is composed of several subcriteria that are briefly explained as follows.

i) Value

- *Alignment with city science vision and strategy*: This subcriterion relates to the overall fit of a city science idea to the existing city science vision and strategy (if one exists).
- *Social impact*: This subcriterion assesses the impact of the city science idea on people and communities in a city. It includes issues such as people's lifestyle, culture,

participation and engagement, health and well-being, personal freedom and privacy, and concerns and aspirations. It is also important to assess whether social impact affects the entire city or a subset of its inhabitants.

- *Economic impact*: This subcriterion assesses the impact of the city science idea on the city's economy. Economic impact can include issues such as gross revenue of the city, employment, wealth, disposable income and skills of the labour force.
- *Environmental impact*: This subcriterion assesses the impact of the city science idea on the overall environment of a city, including the urban natural environment and resources (e.g., city water, energy, emissions, air, land, waste disposal).

ii) Ease of implementation

- *Implementation cost*: This subcriterion measures the total cost of and requisite financial resources for implementing the city science idea.
- *Implementation timeframe*: This subcriterion relates to the total implementation time of the city science idea.
- *Implementation resources requirement*: This subcriterion relates to the human resources requirements for implementation of the city science idea.
- *Implementation risk*: This subcriterion encapsulates various risks that may potentially arise during the implementation of the city science idea. Consideration of the following factors may help in assessing various risks.
    - *Political, economic, social, technological, environmental and legal (PESTEL) barriers*: This factor captures the PESTEL barriers that exist in the city that may hinder the implementation of the city science idea.
    - *Complexity*: This factor reflects the complexity of implementing the city science idea in terms of number of stakeholders involved and various uncertainties involved in implementation, dependencies, connections to other initiatives or action items in the city, etc.
    - *Competence and knowledge*: This factor includes the extent to which the city science idea can be implemented by harnessing existing knowledge and skills in the city as an overall ecosystem.
    - *Regulatory and legal concerns*: This factor covers to various ramifications related to regulations and laws on aspects such as health, safety, and privacy within the city regarding the city science idea.
    - *Ethical issues*: This factor captures various ethical concerns that may potentially arise during and after the implementation of the city science idea.

The city can adopt a simple scoring system for various criteria and their subcriteria, e.g., of three (low, medium, high) or five levels. The scores can be determined either quantitatively or qualitatively relying on available data and optional analyses. Having a well-defined prioritization approach helps cities to facilitate relative scoring among city science ideas.

The city can apply the prioritization approach described previously and can evaluate all formulated ideas.

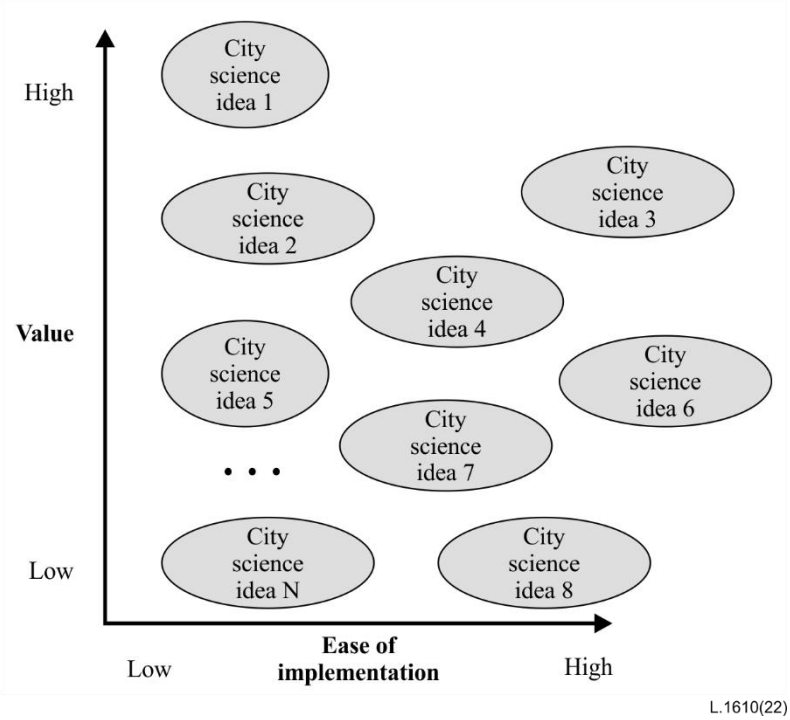

Figure 1 – Evaluation of city science ideas

Figure 1 shows how the prioritization mechanism can be used to facilitate the selection of a subset of city science ideas by applying well-defined criteria. City administrators can subsequently short-list city science ideas for implementation, such as selecting high value and easy to implement city science ideas. Similarly, low value and relatively highly difficult city science ideas may be either eliminated or given low priority during implementation.

Hence, at the end of step 2, the city will have a concrete list of city science solutions for implementation. The city can then prepare an implementation plan by deciding which city science solutions to initiate and when certain constraints such as resource availability may determine actual implementation timings. City science solutions can be phased out depending on constraints, dependencies and their mitigation timeframes. In some cases, cities may opt to reduce implementation risks before commencing implementation.

9.3 Step 3: Boost city science applications

Some of the enablers discussed previously can be utilized during this step to potentially enhance the effectiveness of selected city science solutions. A city can utilize an appropriate mix of the enablers described previously to implement its own city science solutions. In other words, combinations of enablers can be used during the implementation. Some examples follow of potential enablers to illustrate the concept.

Various tools can be used to overcome awareness gaps, such as: programmes in education and training, universities and vocations, and to enhance skills and competencies; existing publications e.g., reports, which can be disseminated to the public, as well as various related entities in city science.

Lack of skills and expertise in both the public and in policy makers can be a potential barrier. Hence, capacity building, peer learning and twinning among cities can be used as potential action items (policy levers).

A city can prioritize its own specific urban challenges to be addressed through city science solutions. Subsequently, the city can utilize an appropriate mix of enablers to boost city science, some of which follow to illustrate the concept.

Strategic planning and city science-related policy making in public and private sectors might be beneficial to adopt a holistic high-level approach.

Financial incentives can be used to boost city science (e.g., tax breaks, reductions, exemptions, holidays, lower loan rates and impact investment).

PPPs and other appropriate financial mechanisms may be used to boost city science.

R&D programmes may be formulated and implemented in collaboration with academia in a city.

Regulations may be used as policy levers and tools to catalyse city science implementations.in some cases.

Award schemes may be formulated to incentivize and encourage both the public and private sectors for city science implementations.

Engaging a broad range of stakeholders may increase the likelihood of success for city science implementations (e.g., public sector, private sector, academia, individuals, NGOs and civil society in general).

Nurturing a rich innovation ecosystem and involving and incentivizing entrepreneurs and small- and medium-sized enterprises to address implementation challenges would help boost city science in a city. Incubators, accelerators, hackathons, etc. might be leveraged to enrich the innovation ecosystem around city science.

Important – Once city science ideas are prioritized and pertinent enablers have been decided, then the following steps can be used to implement each city science solution in line with its own plan:

a) identify the problem;

b) model the problem;

c) solve the model;

d) apply the model solution to the urban problem and utilize enablers to implement city science solutions in the real context.

The aspects of the real city for which city science solutions are implemented will shape and impact specific solution characteristics and the enablers selected.

9.4 Step 4: Assess projected city science applications impact

This step involves either interim or final assessment of the results of implementing city science solutions in a city. Cities are strongly recommended to conduct assessments comparing actual outcomes retrospectively and objectively with respect to those intended. Similarly, the city can evaluate various enablers for their effectiveness during the implementation. Gaps in them can be identified to address and correct in due course. Lessons learnt can be derived to understand the positive and adverse consequences of city science solutions. The positive aspects of one successful city science solutions may be potentially cross-utilized among others; e.g., a successful policy in one solution may trigger the use of a similar policy approach in another. Such examples can be extended to other enablers as well. On the other hand, identification of ineffective enablers would result in their potential relinquishment in due course.

City science solutions are interventions in an urban context and inevitably lead to various transformations. Therefore, it is important to assess their impact retrospectively. An ex-post impact assessment would be highly beneficial to understand the various social, economic and environmental changes that have occurred in the city and compare them to those intended prior to implementation. The comparison of ex-ante and ex-post impact assessments will indicate deviations in terms of intended and actual outcomes. Such deviations may aid in planning more accurately in due course or fine tuning city science solutions.

10 Case studies

To illustrate the application of the city science framework, this Recommendation has included the following case studies that are presented in detail in [b-ITU-T L.Suppl.51].

10.1 Air quality management in Southern California – USA

Air pollution has been one of the leading environmental concerns in Southern California. In response, the district has implemented a digital "Envirosuite" platform that utilizes data about air quality, weather, emission rates, etc., to formulate a baseline scenario on air pollution of the region, which allows officials to identify the source of pollution and take action accordingly.

10.2 Happiness Meter – Dubai, UAE

The vision of Smart Dubai is to become the happiest city on earth. In this context. Smart Dubai embraces emerging and frontier technologies to create happy and seamless citywide experiences. To gauge happiness at the city level, Smart Dubai has implemented a simple yet powerful tool, called the Happiness Meter, to collect data from thousands of touch points in the city instantly to reflect city resident and visitor experiences in Dubai.

10.3 Crime prediction for more agile policing in cities – Rio de Janeiro, Brazil

As the crime rate of Rio de Janeiro has been steadily climbing, police forces have been experimenting with the use of predictive analytics to identify crime hotspots and thereby allocate resources more efficiently. The mobile phone application developed in this case utilizes data and machine learning to determine crime hotspots. Crime data is also made available to the public to improve transparency and accessibility.

10.4 Data-driven energy savings in the Hyperdome shopping centre – Queensland, Australia

Recognizing the growing concern over increasing energy consumption of buildings, Logan City in Queensland has adopted different measures to improve the city's sustainability by reducing energy usage. The Logan City Hyperdome shopping centre, one of the largest single storey shopping centres in Australia, has implemented a series of intelligent solutions to optimize its energy efficiency and reduce energy consumption.

10.5 Fine Dust Filtration – Stuttgart, Germany

Growing awareness of air pollution among the public in Stuttgart has encouraged local technology firms, the Ministry of Transport of Baden-Württemberg and the other public sector members to collaborate on developing filter cubes that utilize data on temperature, humidity, particulate count and other important indicators to reduce fine dust in the air. Collaboration among different local stakeholders in this case provides valuable lessons on successfully implementing a city application.

10.6 Rashid, City Concierge – Dubai, UAE

As part of its vision to become the happiest city on earth, Smart Dubai created a city enablement layer to utilize AI for city happiness. Rashid (literally "guide" in Arabic) combines cognitive computing and natural language processing to help residents, visitors and businessmen in Dubai to answer their queries about doing business, living and visiting the city. Hence, Rashid acts as a City Concierge and a virtual assistant to help its users for any enquiries they might have about Dubai, which in turn promotes the happiness of Dubai residents and visitors.

10.7 Adaptive Circular Cities – Amsterdam, Netherlands

More frequent and severe climate events have propelled the Dutch Ministry of Economic Affairs to formulate a new strategy to cope with their consequences, especially flooding. The Adaptive Circular

Cities project uses 3D modelling to describe the cascading effects of potential flooding. This 3D model simulates a flooding scenario using different variables and data, allowing officials to visualize the direct and indirect impact of the flood and take adaptive measures accordingly.

10.8 Unlocking the potential of trust-based AI for city science and smarter cities

Data and information are collected and analysed through various entry points or interfaces in smart cities or any large-scale digital platforms. These platforms process a large amount of data. Without proper safety mechanisms to govern each transaction, personal data are vulnerable to theft. A trust-based management system that is powered by AI in a distributed network has great potential to secure each transaction, allowing data to be freely traversed to different domains and across different platforms safely.

11 Conclusion

Cities globally face a myriad of urban challenges. This Recommendation proposes that, as a novel inter-disciplinary field, city science has potential to address and resolve various urban challenges systematically and scientifically. Some of the conclusions from the framework and the real-life case studies in this Recommendation follow.

- City science as an inter-disciplinary novel field can be utilized to solve real urban challenges.
- The proliferation of city data available from a wide range of urban sources (e.g., mobile devices, IoT sensors) acts as input to city science.
- The algorithms and the mathematical models and techniques utilize city data to provide solutions to urban challenges.
- The fusion of cyber and physical systems provides an opportunity to address urban physical challenges through digitization and ICT-based techniques.
- Urban challenges and priorities, smart sustainable city strategies of city administrations, and urban requirements of citizens can act as a viable demand for city science with concomitant commercial potential in some cases.
- The advent of city science can help entrepreneurs and businesses innovate and also commercialize new city science solutions.
- Cities can engage a broad range of stakeholders for city science reflecting different perspectives, as well as demand and supply issues.
- City administrators have at their disposal to encourage and incentivize city science a wide range of tools described as enablers in the city science application framework in this Recommendation (e.g., regulations, policies, awareness and a start-up ecosystem).
- Exchange of knowledge and city science solutions at the local, regional, national and international levels will help develop city science as a novel field and will also increase its sustainability while providing solutions to real urban problems across the globe.
- It would be beneficial to assess the impact of city science solutions from social, economic and environmental perspectives. Understanding the predicted and actual consequences of city science solutions will help assess their effectiveness and will also enable further improvements.
- As a scientific discipline, city science can considerably benefit from research and development (R&D) programmes boosting city science solutions. The specific aspects of urban challenges demand particular solutions and modelling techniques to be developed along with their specific data requirements. Hence, focused R&D can generate substantial innovation in city science.

Cities can capitalize on city science by turning it into a viable economic subsector while simultaneously addressing and solving their own urban challenges. With the participation of different scale cities and collaboration among them, city science can prove to be an innovative global field amalgamating data, emerging technologies and city problem-solving techniques.

Annex A

City science enabler assessment

(This annex forms an integral part of this Recommendation.)

Table A.1 can be utilized by cities to assess their current status with respect to city science enablers specified in the city science application framework.

Table A.1 – City science enabler assessment through high-level questions

Assessment element	Currently exists	Brief description	Comments
Are there awareness programmes for city science solutions in the city?	☐		
Are there skill-boosting programmes to enhance and enrich city science applications in the city?	☐		
Are there existing open source solutions being utilized to address city challenges?	☐		
Are there awards in place to recognize successful city science solutions?	☐		
Are there existing skills in place within public and private sectors to implement city science solutions?	☐		
Are city stakeholders currently aware of city science solutions in the city?	☐		
Are broad stakeholders identified for city science solutions?	☐		
Are there existing collaborations and partnerships in place among city stakeholders for city science solutions?	☐		
Are there city science-related existing strategies and policies in the city public and private sectors?	☐		
Does the city provide its urban challenges to be addressed through city science solutions or provide its urban area as a laboratory for city science solutions?	☐		
Are there existing financial incentives in the city for city science implementations?	☐		

Table A.1 – City science enabler assessment through high-level questions

Assessment element	Currently exists	Brief description	Comments
Are there existing PPPs in the city for city science-related implementation projects?	☐		
Are there existing R&D programmes and other targeted academic programmes for city science-related implementation projects?	☐		
Are there regulations and laws (e.g., laws, directives, legislation, standards) supporting or impeding city science-related implementation projects in the city?	☐		
Are stakeholders in the city engaged broadly for city science-related implementations?	☐		
Is there a vibrant and rich innovation ecosystem in the city to address and implement city science-related implementations?	☐		
Does the city utilize data standards or participate in the formulation of related data standards?	☐		
Does the city collaborate with other local, regional, national and international cities to boost city science solutions?	☐		

Bibliography

[b-ITU-T L.Suppl.51] ITU T L-series Recommendations – Supplement 51 (2022), *Case studies on city science application framework.*

[b-FIDO Alliance] FIDO Alliance (2020). *Membership agreement*. Mountain View, CA: Fast Identity Online Alliance. Available [viewed 2022-10-05] at: https://media.fidoalliance.org/wp-content/uploads/2019/12/FIDO-Alliance-Membership-Agreement.pdf

[b-ICC] Investopedia (2021). *Chamber of commerce: What it is, what it does, how it makes money*. Available [viewed 2022-10-07] at: https://www.investopedia.com/terms/c/chamber-of-commerce.asp .

[b-IPCC] IPCC (2018). *Global warming of 1.5 ºC*. Intergovernmental Panel on Climate Change. Geneva: Intergovernmental Panel on Climate Change. Available [viewed 2022-10-04] at: https://www.ipcc.ch/sr15/

[b-ODH] Open Data Handbook (Internet). *What is open data?* London: Open Knowledge Foundation. Available [viewed 2022-10-05] at: https://opendatahandbook.org/guide/en/what-is-open-data/

[b-QHSE] QHSE Management Systems (2018). *Social & public sectors*. QHSE Management Systems. Available [viewed 2022-10-05] at: https://www.qhseworld.com/social-public-sectors/

[b-U4SSC C] United for Smart Sustainable Cities (2019). *Connecting cities and communities with the sustainable development goals*. 180 pp. Available [viewed 2022-12-10] at: https://www.itu.int/en/publications/Documents/tsb/2017-U4SSC-Deliverable-Connecting-cities/mobile/index.html

[b-U4SSC F] United for Smart Sustainable Cities (undated). *City science application framework*. Geneva: ITU (coordinator). 34 pp. Available [viewed 2022-10-04] at: https://www.itu.int/en/publications/Documents/tsb/2019-U4SSC-City-Science-Application-Framework/index.html

[b-U4SSC SDG] United for Smart Sustainable Cities (undated). *Connecting cities and communities with the sustainable development goals*. Geneva: ITU (coordinator). 180 pp. Available [viewed 2022-10-06] at: https://www.itu.int/en/publications/Documents/tsb/2017-U4SSC-Deliverable-Connecting-cities/mobile/index.html

[b-UN] UN (2018). *68% Of the world population projected to live in urban areas by 2050, says UN*. New York, NY: United Nations Department of Economic and Social Affairs. Available [viewed 2022-10-04] at: https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html

[b-US Legal 1] US Legal (1997-2022). *Private sector law and legal definition.* Brookline, MA: airSlate. Available [viewed 2022-10-05] from: https://definitions.uslegal.com/p/private-sector/

[b-US Legal 2] US Legal (1997-2022). *Public sector law and legal definition.* Brookline, MA: airSlate. Available [viewed 2022-10-05] from: https://definitions.uslegal.com/p/public-sector/

[b-WA] Wikipedia (2022). *Academy*. Available [viewed 2022-10-07] at: https://en.wikipedia.org/wiki/Academy.

[b-WCM] Wikipedia (2022). *City manager*. Available [viewed 2022-10-07] at: https://en.wikipedia.org/wiki/City_manager.

[b-WDS] Wikipedia (2022). *Data science*. Available [viewed 2022-10-07] at: https://en.wikipedia.org/wiki/Data_science.

[b-WNGO] Wikipedia (2022). *Non-governmental organization*. Available [viewed 2022-10-07] at: https://en.wikipedia.org/wiki/Non-governmental_organization .

[b-Cohen] Cohen, S. (2013). What do accelerators do? Insights from incubators and angels. Innov: Technol. Gov. Glob. **8**(3-4), pp. 19–25. doi: https://doi.org/10.1162/INOV_a_00184

SERIES OF ITU-T RECOMMENDATIONS

Series A	Organization of the work of ITU-T
Series D	Tariff and accounting principles and international telecommunication/ICT economic and policy issues
Series E	Overall network operation, telephone service, service operation and human factors
Series F	Non-telephone telecommunication services
Series G	Transmission systems and media, digital systems and networks
Series H	Audiovisual and multimedia systems
Series I	Integrated services digital network
Series J	Cable networks and transmission of television, sound programme and other multimedia signals
Series K	Protection against interference
Series L	**Environment and ICTs, climate change, e-waste, energy efficiency; construction, installation and protection of cables and other elements of outside plant**
Series M	Telecommunication management, including TMN and network maintenance
Series N	Maintenance: international sound programme and television transmission circuits
Series O	Specifications of measuring equipment
Series P	Telephone transmission quality, telephone installations, local line networks
Series Q	Switching and signalling, and associated measurements and tests
Series R	Telegraph transmission
Series S	Telegraph services terminal equipment
Series T	Terminals for telematic services
Series U	Telegraph switching
Series V	Data communication over the telephone network
Series X	Data networks, open system communications and security
Series Y	Global information infrastructure, Internet protocol aspects, next-generation networks, Internet of Things and smart cities
Series Z	Languages and general software aspects for telecommunication systems

Printed in Switzerland
Geneva, 2023