Ministry of Housing and Urban Affairs
Ministry of Electronics and Information Technology

Government of India

IUDX

INDIA URBAN DATA EXCHANGE

23 February 2021

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Foreword

MoHUA Smart Cities Mission

With the launch of the Smart Cities Mission in 2015, India started charting a new path towards urban transformation. Building cities of the future, which provide good quality of life, improved economic robustness and harmony with nature needed a paradigm shift in approach towards cities. The Government of India through its Ministry of Housing and Urban Affairs has started work on a three-tier strategy of revitalization of its urban areas. India's cities are changing.

The scale of effort needed is huge. The country has more than 8,000 towns and cities, and creating an impact over the entire geography and for all sections of the population would need time. However, with the right approach, impactful change at scale can be achieved in shorter periods of time and in a much more holistic way.

Building right collaboration with all actors in the quadruple helix- citizens and communities, industry and young budding entrepreneurs in particular, academia and research institutions and governments at all levels is vital for urban solutioning at scale and speed, as needed by India of today. Harnessing cutting edge digital technologies in an appropriate manner with 'citizen at the core' being the guiding principle is extremely important.

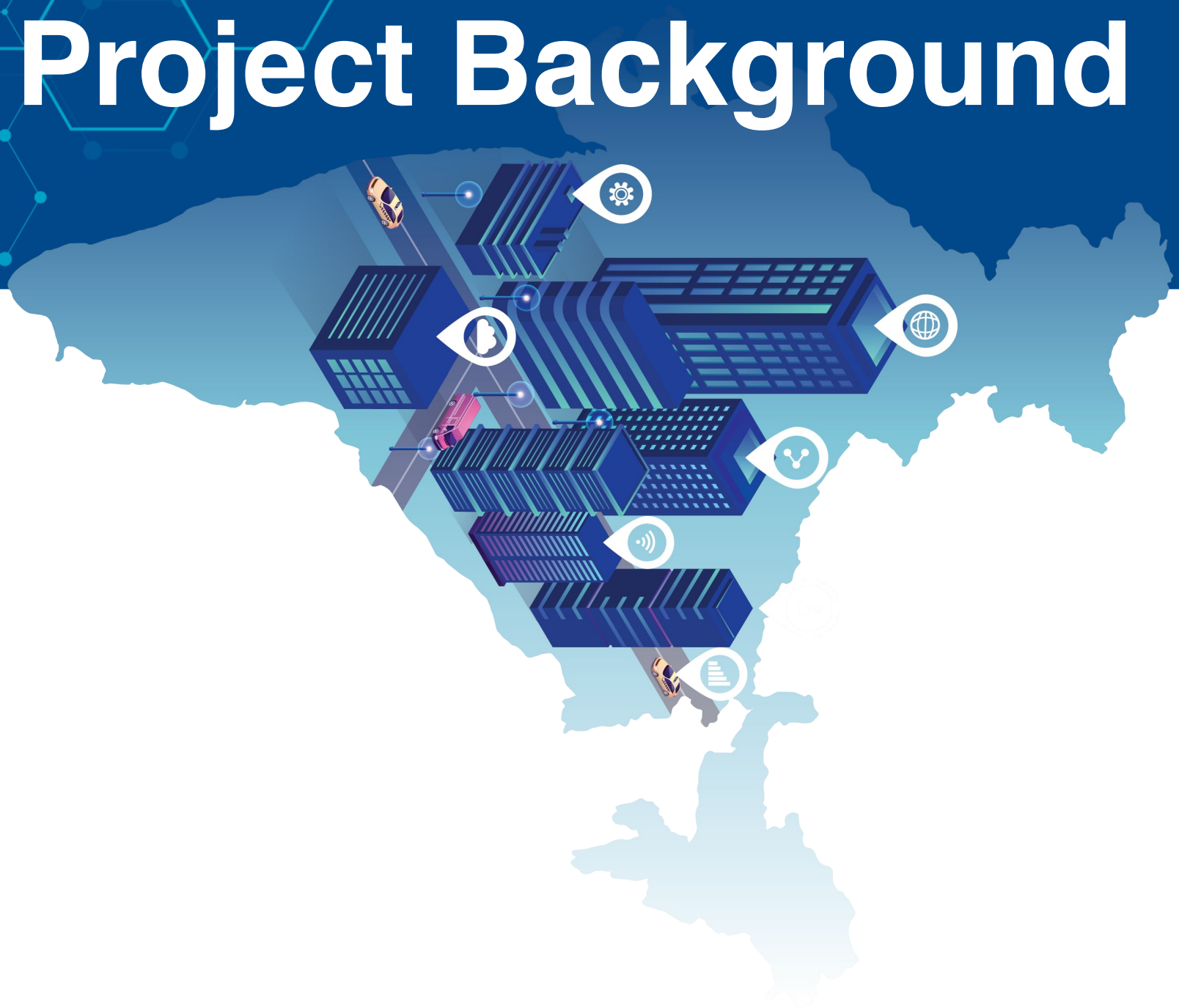
Needless to say, data is at the core of this collaboration. It is at the core of innovation and at the core of technology. How we manage, exchange and use data and the insights that it helps us create will be crucial to our success in resolving highly complex problems faced by our cities today. Data has a crucial role to play in empowering our cities. It has the power to give voice to citizens, make them more engaged in day-to-day affairs of running the city. It will also play a crucial role in promoting open innovation; co-creation and eliminating siloed approach in the cities. Data driven decision-making will help us evaluate performance and take informed decisions on projects that are important to the lives of the millions of people who live in Indian cities.

The Smart Cities Mission is committed to incorporating data-intelligence in decision-making as a way forward in addressing urban challenges of present and future. For this, the Mission has launched several initiatives that will not only ensure integrated development across various aspects of the urban sector, but also catapult the Mission to the next stage of innovation.

The IUDX platform is one such initiative created in partnership with the Indian Institute of Science, Bengaluru (IISc). It is an open source platform designed to enable efficient utilization of data and leveraging of investments, while creating more opportunities for different market players. It facilitates secure, authenticated and managed sharing of data amongst various data platforms and helps cities to strategically focus on unlocking the power of urban data in key sectors.

The Smart Cities Mission intends to initially implement the IUDX platform for the existing 100 Smart Cities through their urban local bodies (ULBs) over a period of next 3-years. These cities will become the lighthouses for all other cities and towns across the country that aspire to emulate a paradigm of data-driven governance.

Project Background



1.1. India's Urban Context

According to the Census of 2011, India's urban population stood at 377.1 million, accounting for 31% of the total. Between 2001 and 2011, the proportion of urban population in India increased by 3.35 percentage points, resulting in the net addition of population to urban areas was 91.0 million. Further, 53 million-plus cities, accounting for 42% of India's urban population, grew twice as fast as the other towns. This upward trend is projected to continue and by 2050, India will have added 416 million urban residents and India's capital, Delhi would have overtaken Tokyo to become the world's largest city (United Nations, 2019).

Along with this increasing concentration of population in urban areas, cities have transformed into engines of economic growth in India. The Economic Survey 2019-20 stated that a total of 13.9 million regular wage and salaried jobs were added in cities between 2011-12 and 2017-18. Estimates by independent scholars place urban India's contribution to the national output between 52.6% and 64.89% (Smart Cities Mission, 2019). Recent projections suggest that by 2030, urban India will account for nearly 75% of the national GDP (CBRE Research, 2019).

In India, cities are governed by urban local bodies which form the third tier of democratic government in the country. The 74th Constitutional Amendment Act 1992 accorded constitutional status to ULBs and provided that urban areas would be governed by one of the three types of ULBs - Nagar Panchayat, Municipal Council and Municipal Corporation, based on the size of the area. Further, the addition of the 12th Schedule to the Constitution provided a list of 18 functions related to urban development that could be devolved to the ULBs by the State Legislatures. At the level of the central government, the Ministry of Housing and Urban Affairs (MoHUA) is mandated to formulate policies, sponsor and support programmes, coordinate the activities of various Central Ministries, State Governments and other nodal authorities and monitor the programmes concerning all the issues of urban affairs in the country.

1.2 . Perspective of Ministry of Housing and Urban Affairs (MoHUA)

The goals of MoHUA's flagship missions draw largely from the Hon'ble Prime Minister's vision for "Sab ka Saath, Sab ka Vikas" (development with all, and for all) policy as well as Government of India's commitment to the 2030 Agenda, including the Sustainable Development Goals (SDGs). Over the last 5 years, Pradhan Mantri Awas Yojana (Urban), Atal Mission for Rejuvenation and Urban Transformation & Swachh Bharat Mission (Urban) have not only transformed the urban realm, but have also greatly improved ease of living for urban dwellers.

On the economic front, the Deendayal Antyodaya Yojana-National Urban Livelihoods Mission has taken meaningful steps towards enabling access to gainful employment for the urban poor. Further, the Smart Cities Mission, with its focus on digital technologies and public-private partnerships, has made great strides in improving the quality of life of citizens in 100 smart cities across the country.

Over the last decade, 'Digital Governance' has taken centre stage in the national policy discourse with the successful implementation of Aadhaar, the world's largest digital identity platform, together with the Digital India Mission, fuelled the development of the India Stack, which has laid the foundation for integrated online public service delivery for the country. Further, e-Kranti: National e-Governance Plan 2.0 has been initiated with the vision of "Transforming e-Governance for Transforming Governance".

Drawing from this collective vision, several ministries and departments within the Government of India (GoI) are working on building an enabling ecosystem to leverage digital platforms for transformative social, economic and governance impact, through a citizen-centric approach.

Alongside the surge in digital governance-related efforts, data protection and privacy concerns have also come to the forefront. Currently, India's data protection is guided by the provisions of the Information Technology Act, 2000 and its amendments. Additionally, the Information Technology (Reasonable Security Practices and Procedures and Sensitive Personal Data or Information) Rules, 2011 also deal with protection of personal information and sensitive personal data. More recently, the Personal Data Protection Bill, 2019 was presented in Parliament and is pending consideration before a Joint Parliamentary Committee.

Policy guidelines on digital governance and data sharing have been notified from time to time. In 2012, the National Data Sharing and Accessibility Policy was notified to facilitate access to data and information owned by the Government of India. Data as made available in machine readable form through a wide area network all over the country in a periodically updatable manner, thereby permitting a wider accessibility and usage by the public. Further, expert committees have been formed in order to study and identify key issues related to data protection. In 2018, the report on 'Data Protection Framework' by the Justice BN Srikrishna Committee suggested that processing (collection, recording, analysis, disclosure, etc) of personal data should be done only for "clear, specific and lawful" purposes. More recently, the Committee of Experts on Non-Personal Data Governance Framework in its draft report recommended a separate legislation be formulated to govern non-personal data and also defined roles and stakeholders in the non-personal data ecosystem.

To create, nurture and further the spirit of data-driven empowerment, collaboration and governance in 100 smart cities, MoHUA has developed strategies, frameworks and methodologies, and provides resources and strategic support to cities to imbibe a culture of data and data-driven decision-making. They provide the foundational pillars and a suggested roadmap for cities to improve their readiness for intelligent use of data in addressing complex urban challenges. The strategy is built on three foundational pillars, namely **people**, **processes** and **platforms**, all of which require a thoughtful approach that enables seamless data-driven interaction while maintaining the privacy and security of citizens. The approach includes:

a) Well-capacitated institutional structures across all tiers of governance along with the formation of networks and alliances;
b) Process enablers-such as policies and standards; and
c) Technology platforms to support implementation of policy intents.

The IUDX programme is creating critical infrastructure which addresses not only c) above but also encompasses aspects of a) and b).

1.3. Perspective of Ministry of Electronics and Information Technology (MeitY)

The Ministry of Electronics and Information Technology (MeitY), with other departments of the Government of India, is working on building an enabling ecosystem to leverage digital platforms for transformative social, economic and governance impact, through a citizen-centric approach. Sector-specific blueprints have been published, including in the Education, Health and Urban sectors. Several state governments such as Andhra Pradesh and Haryana are adopting a platform-based approach in order to enable seamless service delivery to citizens. MeitY has also conceptualized the India Enterprise Architecture (IndEA 2.0) to reimagine the delivery of government services.

While efforts to study these innovations have focused considerably on understanding technology best practices, the non-technology aspects of these initiatives, such as governance, operational management and user-engagement are equally, if not more, critical. In addition to getting the technology right, it is particularly important to ensure that future platforms are designed sustainably and "responsibly". This means ensuring robust governance for the platforms including their institutional accountability, regulatory frameworks, personal data privacy, security and risk management, talent management and sustainable financing.

MeitY has already undertaken significant initiatives in this direction. Some of these include: A policy on Open APIs for Government of India (backed by a directory of APIs - API-Setu), an Electronic Consent Framework, a Personal Data Protection (PDP) Bill, and a Committee of Experts on governance of non-personal data which has produced a recent pioneering report in this area.[1] The overall concept is captured in the formulation of a 'National Open Digital Ecosystems' (NODE) strategy[2], i.e. open and secure digital delivery platforms, anchored by transparent governance mechanisms.

IUDX fits squarely into this overall set of activities and is consistent with the NODE strategy as outlined above. It relates to a specific sector of great importance—the urban sector—and is becoming widely deployed in urban centres. In addition, the core concepts in IUDX provide a model that will be explored for broader adoption across sectors. Specifically:

- The concept of a Data Exchange is central to the IndEA2.0 core architecture (as shown in section 3.4.). IUDX provides an excellent case study for a data exchange as detailed there.
- Furthermore, it is open source and entirely standards based, ensuring consistency with the goals of the IndEA 2.0 architecture and MeitY strategy for national infrastructure.
- IUDX is harmonized with the API-Setu initiative and the IUDX APIs will appear in the API-Setu directory. This ensures a level of consistency across MeitY's different initiatives.
- IUDX deployments provide an excellent test-bed for the evaluation of data governance models as formulated by the above referenced MeitY NPD report by the panel of experts.

MeitY will actively explore how to adopt IUDX concepts and experiences in other sectors.

[1] See https://static.mygov.in/rest/s3fs-public/mygov_160922880751553221.pdf
[2] See https://static.mygov.in/rest/s3fs-public/mygov_158219311451553221.pdf

Problem Statement

2.1. Motivation – Getting Control of Data

Cities around the world have learned that they possess a new valuable asset, namely the data generated by their various departments and agencies. Some of the data consists of streams of IOT data from installed sensors (e.g. Air Quality, Traffic, etc), some of the data is demographic or geographical, some may be from municipal tax or property records, some from legal documents or registrations, and some may be historical data from archival sources. Each set of data has its own security and privacy consideration, as well as commercial, monetary or subscription aspects which must be observed. Cities such as Copenhagen[1], Columbus[2] and Manchester[3] have taken ownership of their data assets by creating data exchanges, which are software platforms that allow controlled sharing of data by providing common ways of accessing and representing the data. An important idea behind a data exchange is that data silos are actually not a bad thing, as each silo often represents a domain-optimized service that performs that function very well. Instead of breaking silos or moving data en masse into a central repository, this approach chooses to interconnect the disparate and distributed entities through a common data exchange.

This provides a way for accessing data in a unified, common format, allowing for sharing of data between different departments in a city, as well as opening up data for third party developers to create innovative new applications and citizen services. In addition, there is an opportunity for third party providers of data, or third-party providers of data analytics or data annotation, to participate in what becomes a data marketplace.

It is important to understand the distinction between a data exchange and an open data platform (such as data.gov.in). A data exchange allows the owner of the data to strictly control data sharing and define which entity has access to the data-sets. It is also possible to define access policies and data pricing models. An open data platform, on the other hand allows open access to all comers, eliminating control of who gets access.

2.2. The Solution

A Data Exchange: Data Exchanges are starting to give cities around the world an opportunity to step up and take control of their vast data resources, enabling improved function of their own departments as well as creating new sources of revenue. This paper describes how Smart Cities can be in the forefront of this wave, through the creation of the India Urban Data Exchange (IUDX). As described in this paper, IUDX will be completely open source, based on an underlying framework of open APIs, data models, and the security, privacy and accounting mechanisms that will facilitate, easy and efficient exchange of data among disparate urban data silos. IUDX draws on ideas and, where feasible, code, from best-of-breed global projects such as CityVerve[4] and Fiware[5]. However, we are heavily skewed towards the Indian ecosystem, cultural norms, city nomenclature, payment and identification systems, etc. and therefore the IUDX solution is particularly suitable for Indian Smart Cities.

[1] See https://cphsolutionslab.dk/en/news/learnings-from-the-city-data-exchange
[2] See https://datasmart.ash.harvard.edu/news/article/how-columbus-accomplishing-its-smart-city-vision
[3] See https://www.manchester.gov.uk/smartercity
[4] See https://cityverve.org.uk/
[5] See https://www.fiware.org/

2.3. Stakeholder Value

It is expected that all stakeholders in the Indian Smart City ecosystem will gain from the initiative. Within each of the Cities, citizens and the community will benefit through the availability of better, more innovative, and cheaper applications and services.

The Cities themselves will benefit from the reduced development cost and faster development times enabled by a standard platform, together with the ability to choose vendors freely and avoid vendor lock-in.

They will see new source of revenue through the unlocking of data assets, and will unleash innovation from entrepreneurs and community, without any cost to themselves. Industry will benefit enormously through the improved ability to find skills and rapidly ramp up projects. They will also see reduced development expenses enabled by a standardized and open-source platform, and be able to focus on innovation and differentiated value rather than design basic platform software. Start -ups, in particular, will benefit from the decrease in heterogeneity IUDX provides.

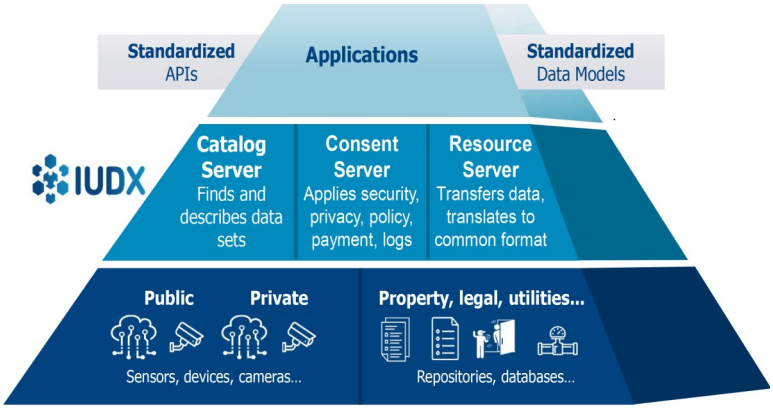
Third party sources of data (such as private apartment complexes) will have a new opportunity to share and monetize their assets. Academic institutions and research labs will be able to conduct more meaningful research by having direct access to a wide variety of data.

The initiative will also provide enhanced citizen and government engagement and promote connected citizen experience. As the ultimate beneficiaries, citizens will see improved infrastructure, efficient public utilities and new economic development activities. The innovative applications and services will also positively impact the cities environmental footprints and create safer communities.

Solution Overview- India Urban Data Exchange

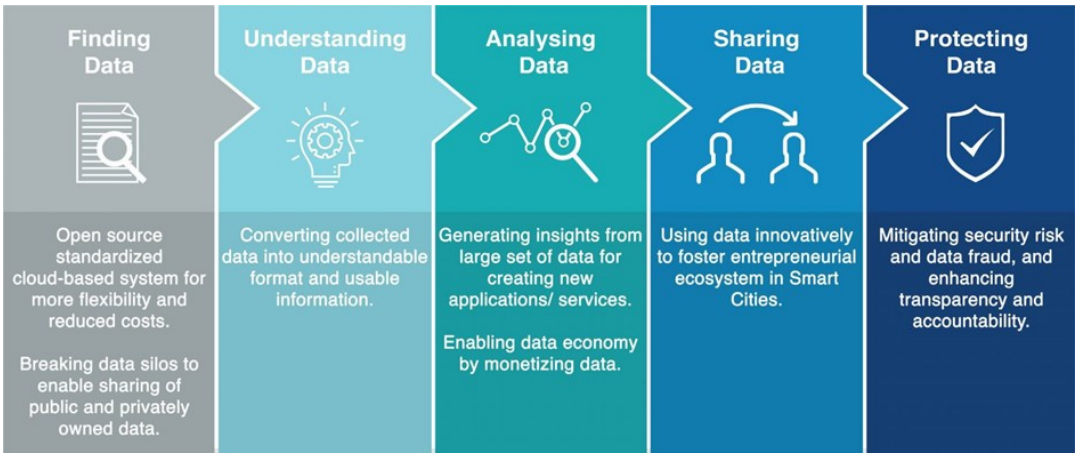
3.1. IUDX Overview

India Urban Data Exchange (IUDX) is an open source software platform that will facilitate secure, authenticated and managed exchange of data amongst various data platforms, 3rd party authenticated & authorized applications and other data sources, data producers and consumers, both within a city to begin with and scaled up across cities eventually at a national level, in a uniform & seamless way. The platform provides full control to the data owners as to what data to expose and to whom. Built-in accounting mechanisms enable connect with payment gateways which will form the foundations for a data marketplace. The whole platform is developer friendly, via definitions of open APIs (application program interfaces) and data schema templates (formats for interpreting data), so that a whole new application ecosystem gets created.



This illustration shows a simplified layered picture of the platform. The lowest layer is composed of a variety of data sources, some public and some private, generating various forms of data. On the top are a variety of applications that use the data to deliver useful services to the city and its citizens. These applications may be created by the city itself or by third parties such as industry partners or entrepreneurial start-ups. The applications will deliver services such as improving mobility, optimizing waste management, enhancing citizen safety, etc. In the middle is the IUDX platform, a cloud based service that delivers three basic functions. A ***catalogue*** server that enables the identification and location of relevant data sets, a ***consent*** server that allows ensures that only those that are allowed to share the data in accordance with policies defined by the data owner can do so, and one or more ***resource*** servers that transfer data from the data provider to the data consumer while transforming the data into a common data format.

3.2. Objectives of IUDX



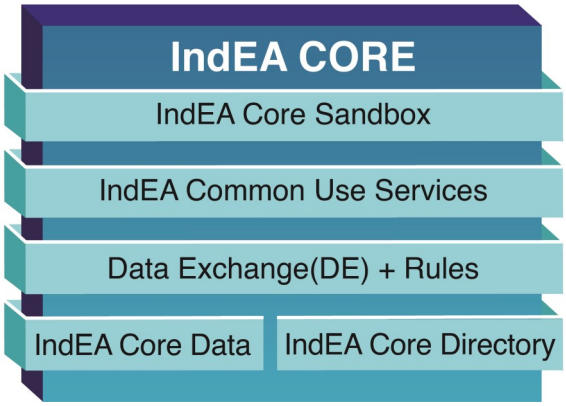
The focus is to enable data exchange between various city departments, between governments & citizens and governments and private sector within a city. It will directly address the issues that inhibit sharing and extraction of maximum value from the City's data. The initiative will essentially create a unified single-point data marketplace for various smart cities ecosystem stakeholders. This will help cities with new revenue sources and create a fertile environment for innovation.

3.3. Operational Aspect

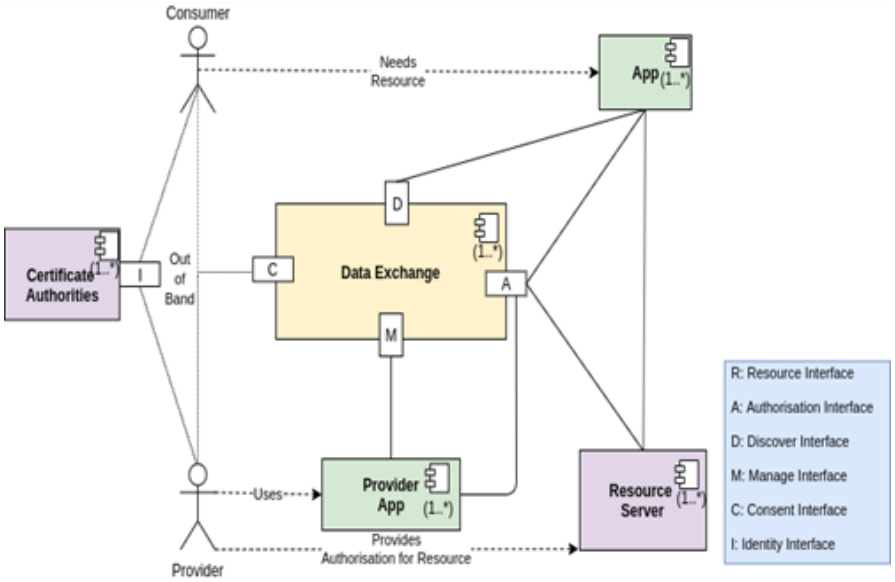
IUDX compliant applications will be able to use APIs to pull data from any of the underlying data platforms and using the publisher APIs to push data to any of the applications behind the individual platforms. Standardized APIs and data schema templates, will enable an IUDX compliant application to work in a city without needing any modification. Additionally, the standardized publisher APIs along with common data schemas, will enable vendor neutrality for IoT devices. In IUDX, there is a clear definition of data ownership and sharing mechanism, under the control of the data owner. The platform itself is only a vehicle for the data owners to more effectively manage and share the data as per their discretion/policies.

3.4. IUDX as a Data Exchange Case Study

The need for a data exchange is specified in various reference architectures.



The IndEA 2.0 architecture specifies a set of core services as shown in the figure. A key service for IndEA2.0 core is the Data Exchange layer which enables controlled sharing of data. This Data Exchange layer is essential in providing data connectivity between IndEA 2.0 services. IUDX is an example of a data exchange and fulfils this architectural role.



The BIS architecture document (IS 18003_1 Unified Data Exchange Part 1 Architecture) describes an architectural model for a data exchange. IUDX follows this model (shown in the figure above).

IUDX Demystified through Real World Analogies

Why is IUDX needed? What does it do for cities? Sometimes it is easier to understand a concept by comparing it to other entities we are familiar with in everyday life. Albert Einstein is quoted as saying, “Analogies let us the understand the world by connecting complex new phenomenon to things we already know.” So, before we go into more technical details, we will explore the value of IUDX using some real world analogies.

Since IUDX performs many different functions, many different analogies are in order. The story of the elephant and the blind men comes to mind: One man touches the legs—an elephant is like a tree he says; another touches the tail—like a rope, he says; another touches the trunk—like a snake, he says; and the final one touches the stomach and declares—like a rock. The truth is actually all of the above—an elephant is a combination of all these attributes but each description is incomplete. IUDX is similar as it offers different capabilities and features to different constituencies but everyone can view things from their own perspective. So, let us go on our own “blind man” exploration of IUDX.

IUDX is like a department store (for all types of data):

Department stores contain clothes, kitchen items, foodstuffs, appliances, etc. The items are organized in clearly marked aisles with common signage, special sales, discounts, etc. So, instead of visiting a dozen different individual stores, a customer can visit the department store, put all different items they need into the shopping cart, and check-out once at the cash register. IUDX similarly collects data from different data silos and presents them in a single consistent form. So, if a data consumer wants to create an application that uses data from different sources (e.g. police, fire, traffic), they will not need to negotiate separately with each department but can obtain all data from a single source—IUDX. Pertinent IUDX attributes: ***Aggregation, Standardization***.

IUDX is like a university library (with data-sets instead of books):

Another way of understanding IUDX is to think of a large public library system such as may exist in a university. Think of each data-set in IUDX as a book in the library. Students visit the library to get the materials they need for their education or research. When a student comes into a library, she looks up the catalogue. The books are numbered in a standard fashion and organized in shelves accordingly, enabling her to easily find the books she needs. IUDX has a similar catalogue and organization for data-sets. Now, suppose that instead of building a library, the university simply dug a few big pits in the ground and threw its books into the pits in a random way. Students would have to rummage through the pits to get the materiel they need. That is a bit like trying to get data without IUDX. Pertinent IUDX attributes: ***Catalogued, Labelled.***

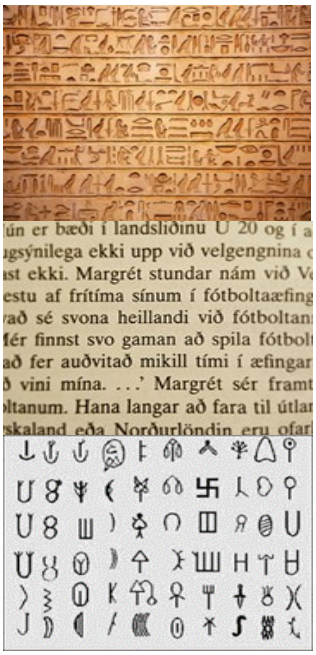
IUDX provides an authorized check-out process like a university library:

Another similarity is that libraries have security to prevent unauthorized use. Only people with authorization (usually affiliation with the university) are allowed to take out books. For example, books in many libraries have scannable RF tags and the entrance is equipped with a detector that scans for any unauthorized books. Just as library materials are protected, IUDX protects data and enables controlled sharing of data that is not open to all. Thus, IUDX offers data from providers that would normally be hesitant to share data. Pertinent IUDX attributes: ***Security, Identification, Authorization***.

IUDX is like a food delivery platform (but for data):

What food delivery platforms do for food, IUDX does for data. These vendors provide a platform to the restaurants, i.e. the food providers and the people willing to order food. Similarly, IUDX also simplifies access to data in a city by bringing all data producers and consumers like PSUs, corporates, startups, etc. on a common platform and making it easy for them to get access to the data points originating from millions of sensors like traffic cameras, RFID readers, IoT devices and other sources as well. Very similar to the food platform vendor's standard UI for restaurants, which helps us navigate easily and choose the items quickly, IUDX supports data standards that can help the consumer quickly integrate the data into an existing workflow. The data can also be searched, filtered, rated and bought like we order food on the food delivery vendor. Pertinent IUDX attributes: ***Platform, Standardized Interfaces.***

IUDX is like an automatic translator (for data):



Suppose all office papers and documents are written in different languages. Some are written in English or Hindi or Tamil and understandable to many people. But many are written in Icelandic or in Ancient Greek or in the language of the Harrapan civilization which is yet to be deciphered. Some are on paper whilst others are on scanned images or possibly inscribed on stone tablets. An office worker would be completely baffled until all documents were translated into a common language and onto a convenient common medium. IUDX performs a similar translation function by enabling data generated in different forms (say, from different vendors or different departments) to be translated into a common data format so it can be understood and absorbed in a consistent fashion. Pertinent IUDX attributes: ***Translation, Standardized Data Model.***

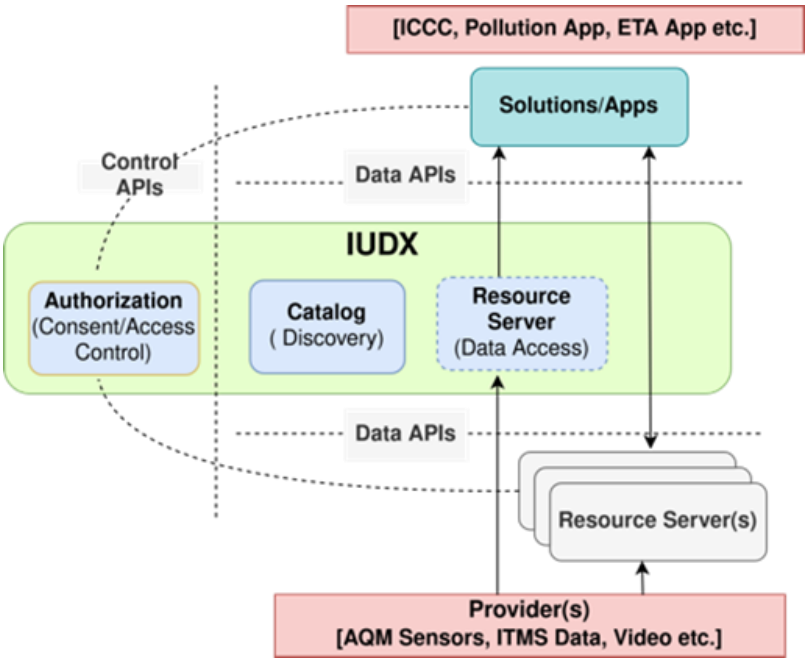
IUDX is like UPI:

The Universal Payment Interface (UPI) was established about a decade ago to transform the Indian payment industry. It was executed as an Open Source project with no private company having the ability to capture any proprietary advantage. A non-profit company, the National Payment Corporation of India (NPCI) was established to build and operate UPI.

NPCI was funded by a consortium of public and private sector banks, working together for common good. NPCI has had enormous impact on the national scene, and has transformed the way electronic payments are done in India. Not only has UPI become a major success, NPCI has been instrumental in nurturing numerous digital wallet companies. These companies have delivered great benefit to citizens and have also become immensely valuable. Pertinent IUDX attributes: ***Open Source, Consortium based, National Impact***.

These analogies can be extended to include more examples. The message here is that IUDX is a powerful platform to enable controlled any-any sharing of all types of non-personal data. It provides a wide variety of services and capabilities for different constituencies. It can be of enormous value to cities, application developers, data providers and, of course, most importantly -- citizens.

IUDX Features / Applications



As discussed previously and shown in the figure above, IUDX consists of three main components:

- A Catalogue Server that allows applications to identify and locate pertinent data resources
- A Consent or Authorization Server that validates data is accessed only by those authorized by data owner and consistent with the specified access policy
- One or more Resource Servers to provide data access and data ingestion through standardized API's and data models. Resource Servers can either be part of the IUDX platform or reside outside the platform.

IUDX enables sharing of data without losing control. It allows data to be located and identified through a catalogue server; ensures the data consumer is authorized access in accordance with the data provider's policies through the consent server; and ensures that data is transferred from provider to consumer in an understandable format through a resource server.

Data resources managed by a Data Provider are hosted on the resource servers and a Data Consumer can access a data resource via open and standard data access APIs. Resource servers also provide publication services to enable data providers to ingest data from their respective data resources. A Data Consumer can discover the data resources relevant to its application using the search APIs provided by the catalogue service. The catalogue hosts information (e.g., data formats, units, type of the resource, etc.) for each data resource. This information is registered and managed completely by the provider of the given resource using open management APIs provided by the catalogue service. The meta-information, which is both human and machine understandable, enables the consumer to understand data and get additional context required for intelligent usage of this data. The Consent or Authorization server provides management APIs to register and modify access control policies associated with a protected data resource. The Consent Server also provides services to get access tokens in case the data consumer needs to access a protected resource. Using token validation services provided by authorization server, a resource server can ensure compliance to the data access policy set by the provider. Some further details of the three components are provided below.

5.1. Catalogue Service

The main functions of IUDX catalogue service are:

- Search and discovery of data resources
- Provide unambiguous description of data from a given resource thereby leading to Improved data understandability and inter-operability
- Provide additional context for a given resource that may improve its usage in applications
- Provide APIs
    - for Text search, Geo-spatial search, Attribute search and Relationship search
    - to create, read, update and delete meta-information objects

IUDX catalogue is a store of meta-information associated with the data resources available with the data exchange. Some illustrative meta-information attributes associated with a resource are: associated provider details, resource sever details where the data can be accessed, location of a sensor device, descriptions associated with the resource, data-sheets if applicable, information whether the resource is public or private etc. The meta-information for a given resource is provided and managed by the data provider of the associated resource. The catalogue uses concepts of linked data to provide semantic contexts for the attributes describing meta-information which leads to improved machine readability, interpretability, operational interoperability and enables vocabulary reuse from other data-model stores and taxonomies. The catalogue items are stored using JSON-LD[6] format which is a lightweight linked-data format based on existing and popular JSON format and is easily readable and writeable by humans. Further, each catalogue item adheres to a schema that specifies a set of mandatory attributes and may contain additional custom attributes. A catalogue item may be related to another catalogue item by providing explicit references to one another.

5.2. Consent Service

The IUDX Consent/Authorization Service allows data sharing while respecting ownership, privacy and compliance requirements. It ensures that only the authorized person can get tokens to access the private/protected data and ensure data access policies specified by the Data Provider are enforced.

The main functions of the service are:

- Resource access authorization to grant access to access-controlled resources
- Resource access policy management to manage policies which specify access rules
- Authentication and registration services
- APIs to provide
    - Operations to request, validate, and manage an access token for a data resource
    - Policies associated with access to a data resource

[6] See https://json-ld.org/

To access a protected data resource, the consumer needs to present a valid authorization token to the resource server. A token can be obtained by using token access APIs provided by the authorization server. Any access token request for a resource by a consumer will be checked against the existing access control policies. These policies are set and managed by the provider of the resource. If the policy decision is a success, an access token is provided to the consumer using which a data access request can be made. The access token is also logged to ensure auditability of consent grant. If no policy exists or no decision can be made, the provider and the consumer may negotiate, outside the scope of the IUDX, to agree to consent terms after which an access policy can be set by the provider. The authorization service also provides token introspection APIs using which a resource server can check the validity of a token presented by the consumer at the time of data access.

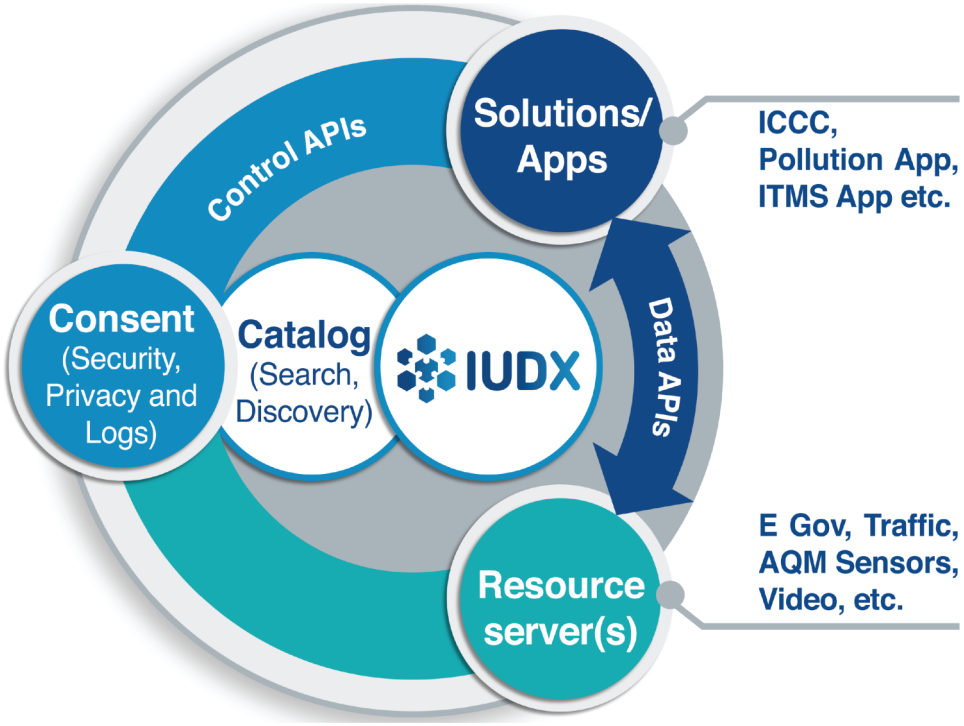
5.3. Resource Services

The resource services constitute the data plane for IUDX and provides data access for the data resources available with the exchange. The resource servers deliver data to data consumers in compliance with the access policy requirements set by the provider of the resource. For this compliance, a resource server must implement a token introspection interface with the authorization server. For any access on a protected resource, the resource server requires the consumer to present an access token which it validates using token introspection APIs before serving the data. Apart from data access APIs, AMQP[7] subscriptions are also supported for streaming data sources. In future, support for call back subscriptions may also be provided. Data is always served over secure and encrypted channels using TLS channels. The resource servers may also provide data ingestion endpoints to allow data to be published into the resource server by data providers.
IUDX resource access APIs are harmonized with ETSI NGSI-LD Specifications. The data access service provides APIs for:

- Search and count: Get data using spatial, temporal, attribute and complex searches
- Subscriptions: Get access to streaming data using AMQP

Note that by design one or more resource servers can exist in an IUDX system. Further, an entity other than IUDX service provider, defined as the entity which is deploying and maintaining the catalogue server and authorization server, can provide for a resource server as long as the resources hosted by it are onboarded on the catalogue, data access complies with the sharing policies set by the provider and the data is served according to the IUDX data access APIs.

[7] See https://www.rabbitmq.com/amqp-0-9-1-reference.html



IUDX adheres to the following key design principles:

- **Open APIs and data models:** IUDX uses open and standard APIs and data models which facilitates inter-operability, data sharing across vertical domains and development of a rich ecosystem of application developers providing innovative, data driven solutions and services.

- **Consent Driven:** IUDX allows sharing of data with a consumer only if an explicit consent is provided by the data provider.

- **User Centric**: IUDX simplifies interactions for both data consumers and providers to enable ease exchange of data and services.

- **Security and Privacy by design:** Security and privacy have been included in the design and engineering of all IUDX components right from the ground up and all the best practices have been followed.

- **Open source:** IUDX is an open source initiative which uses leading tools, technologies from the open source industry and adopts industry best practices.

- **Scalable by design:** IUDX incorporates a scalable micro-services-based architecture for all its components that allows it to adapt to the diverse scale of operations encountered in various urban data exchange settings. Further, IUDX lends itself easily to vendor agnostic cloud deployments.

Partnerships/ Implementation

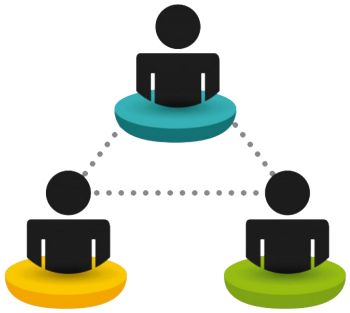
6.1. Governance and Operating Models

Since IUDX is set up as a collaborative project, broad involvement of city, industry, entrepreneur, community and governmental is essential for the project to succeed. Industry partners will provide key technical skills and guidance for the project. The operation of IUDX is governed by a board of advisors, a technical steering committee, and a data policy and ethics committee. To understand the need for three distinct governing bodies, we should understand that IUDX has three distinct aspects.

6.1.1. Non-Profit Entity

IUDX operates as a non-profit company (it is technically a subsidiary of a non-profit operated by IISc) and it functions as any other company. Normal corporate governance is provided by the Board of Advisors as described below.

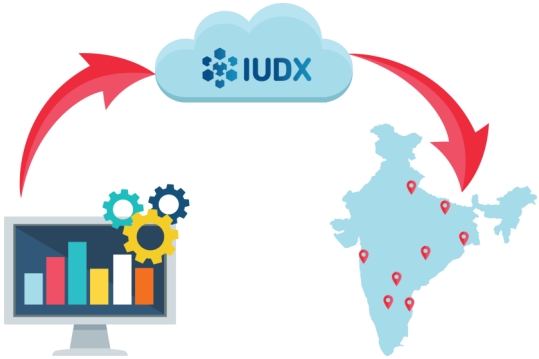
6.1.2. Collaborative open source body



IUDX has, as its core function, the creation of the Open Source Data platform. This will be done as a collaborative effort, involving technical participants from industry and academia. The Technical Steering Committee, modelled after best-of-breed open source bodies, provides the transparent governance necessary to ensure that technical choices are based on merits and not partisan interests.

6.1.3. Operating a platform

Since IUDX will operate the platform as a cloud service and provide it to Cities that join. In this role, IUDX will connect to data providers and application providers, and may store data for analytics or other purposes. The Data Ethics and Policy committee will provide the guidance and overview necessary for this aspect.



6.2. Partnership Ecosystem

6.2.1. Need for Partners

IUDX will only succeed if there is a strong partnership and collaboration with the broad public data ecosystem. While some of the relationships will be ad hoc and informal, we expect many to be formalized as “memberships” in a IUDX consortium. The IUDX consortium and its membership will form the core of a community -based governance and operational model.

6.2.2. Types of Partners

Partners will fall into one of the following categories. A brief summary of the category, role and responsibility is provided.

1. Research partners

These are typically academic institutions, independent research organizations, or governmental research entities. These members will have active research programs in areas related to IUDX.

2. Industry Members

This includes Indian companies, multinationals with operations in India, government-owned for -profit companies, and start-ups that are creating software, hardware or related services that relate to IUDX. Industrial members provide expertise and skills to IUDX. In some cases, they will assist in use cases and applications for cities. In other cases, they will create open source components or enhancements of the IUDX platform. IUDX will create a formal IUDX consortium structure for industry engagement.

3. Governmental and International Partners

This includes the city/state/central government agencies involved in urban governance and other governmental agencies. It also includes organizations such as development banks, trans-national organizations (such as the EU) and other international bodies that have strong expertise and/or advocacy for smart cities.

4. Policy, Advocacy, Expert members

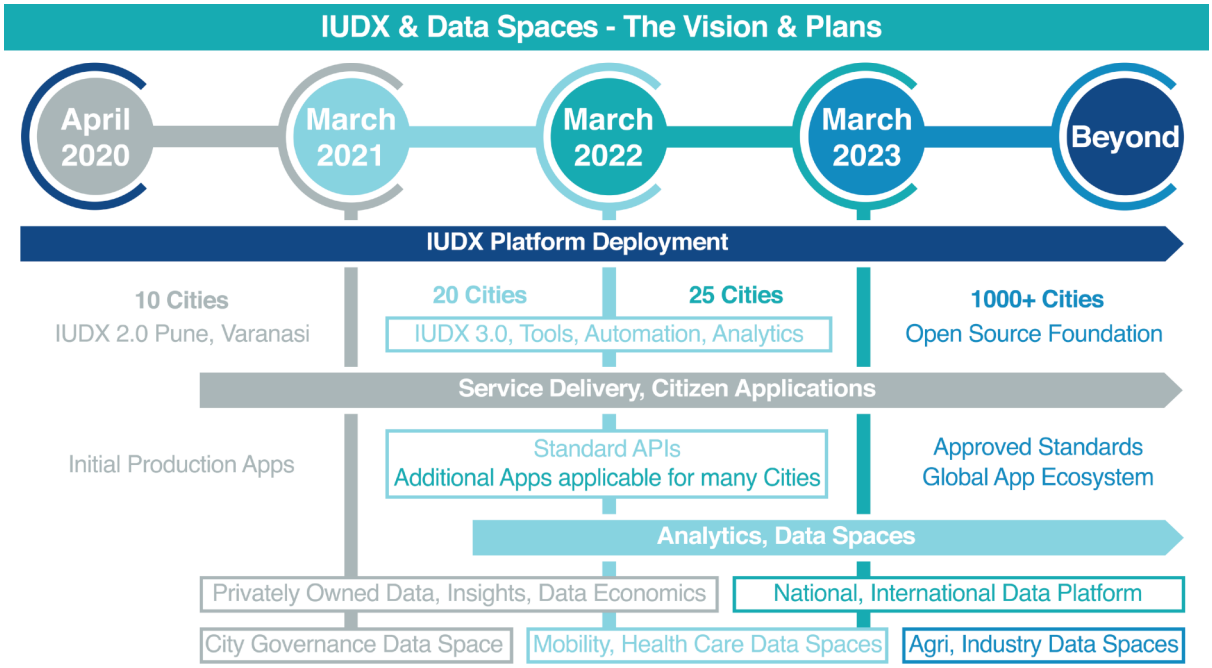
NGOs, Think-Tanks, Policy Advocacy groups in the Urban Domain making policy decisions and/or recommendations. They will foster IUDX engagement with the civic communities and act as an advocacy arm of IUDX for promotion of data policies. Also, we include organizations or individuals with specific areas of expertise of relevance to IUDX. For example, a variety of Civic or other citizen groups, technical standards groups such as TSDSI, or other open source entities such as FIWARE.

Deployments

The IUDX platform described above is a software, which needs to be deployed and operated as part of the overall Smart City IT infrastructure. Since IUDX is a data exchange and not a data repository, it provides considerable deployment flexibility and not a rip-and-replace deployment. It is designed to add value in the existing deployments (brownfield) with no disruption to existing platforms and of course for the new deployments (greenfield) without any challenge. The IUDX components (Catalogue, Consent, Data) along with the API adapters, will allow the existing data in their data platforms to be searched, requested, permitted and exchanged.
IUDX is targeted to be deployed in its own cloud instance, but could be deployed in a traditional on-premise model too if it is required to meet any specific requirements. The high data bandwidth video data will be hosted locally to meet latency and cost considerations. Multiple domains and cities could be connected to umbrella IUDXs to exchange data at the region, state and national level.

7.1. City Engagements

Deployment of IUDX is a partnership between the IUDX team, the city administration, their vendors and system integrators, and the Ministry. The deployment will only succeed if all parties work together. The team has a deployment process designed to make the IUDX implementation easier, faster and impactful and enable the industry/start-up ecosystem to solve the city's specific challenges using data. The typical cycle is 3-4 months. Since IUDX program is envisaged as a long-term investment on behalf of the nation, it has a defined deployment trajectory for the next three years. The pilot projects and deployment across 3 pioneer smart cities have been a success and we plan to bring another 7 cities under the IUDX umbrella in 2020, 20 cities in 2021 and 25 cities in next year.



7.1.1.Benefits for City Management

The IUDX program has been designed keeping the requirements of the city management councils in mind. Here are the benefits that a city management can be derive:

- If the city has an ICCC system, IUDX will integrate with the existing APIs and provide the ability to share data coming from city solutions and also from other private and public sources that are not currently being sent to ICCC
- If the City does not have ICCC then IUDX will allow an ICCC app to be created that can provide ICCC function at a dramatically lower cost
- As IUDX integrates solution APIs of multiple vendors, the system will become vendor agnostic and hence no lock-in with the first vendor for renewals. This is because of open source and open standards.
- Access to pre-negotiated relationships with private data providers where privately owned and public data would be needed to solve some of the City's pressing problems.
- Access to the IUDX AppStore portfolio of independent app developers to readily use the existing applications and also to develop the new ones, to solve specific city challenges.
- Additional revenues through data monetization, reduced cost of city operations through efficient service applications and Citizen's satisfaction through applications for their convenience.

7.2. Use cases for implementation

IUDX has been successfully deployed in three pioneer cities - Surat, Pune and Varanasi. All the three cities are working on multiple use cases to create solutions addressing some of the major civic issues.

7.2.1. Pune Smart City – Improving City Safety and Night Travel

Pune has created a phone-based app, where people will be able to plan trips while taking safety considerations into account and avoiding unsafe areas/ streets. Citizens, public transport, and law enforcement agencies are the intended customers of this application, where the safety index for the streets/places will be identified based on a variety of road safety parameters. For this the datasets will be collected in the form of location wise reported crime data, surveillance camera feeds, street light locations/status, number of people on the street, and crowdsourced 'feeling' data. This application will be live soon for use by the general public. Some of the features of the project are:

- Safety index computed using an algorithm based on various data sources such as street light status, crowds, gender diversity, etc
- Incorporation of Safety Index into IUDX for use in navigation and other services
- Real time updates of safety index based on IUDX data
- Use of analytics on IUDX data to derive safety parameters
- Integration with navigational apps or tourist guides

7.2.2. Varanasi Smart City – Solid Waste Management

Managing waste collection and disposing it has been an area of concern for all the Indian cities. IUDX has worked with Varanasi Smart City to come up with a solution to alleviate the issue. An app has been created from the data obtained through IUDX, with the help of which the city sanitation department will be able to accurately estimate wet and dry waste volumes allowing them to optimize pickups and to plan for sale and recycling of wet waste, reducing pollution and opening up business opportunities.

Some of the features of this project are:

- Volume Sensors installed in Bins to identify the level of solid waste
- RFID Tagging/Geo-tagging of all garbage bins and garbage points to allow real-time tracking of waste collection
- GIS/GPS enabled Solid Waste Management for online tracking of waste collection vehicles, their routes and attendance of staff
- Workshop Management System for Vehicle Breakdown Details
- Fuel Management system to identify the gaps in Vehicle run
- Integration with Weighbridge to identify the Garbage collected and sent to Garbage Treatment Plant
- Monitoring of collection of bins (Full or partial)
- Identify the weight of Garbage as per Volume Sensors data

7.2.3. Surat Smart City – Bus Occupancy Status

Surat has a comprehensive Public Transport System consisting of BRT Buses, City Buses and High Mobility Corridor Buses with the current ridership of around 2.4 lakhs. The Bus Occupancy Use Case organises and onboards data on IUDX from sources such as ITMS, Surat Money Open Loop Smart Card, QR code-based ticketing, and Google's bus-related real time data. This data is used to derive the actual time of bus arrival and the number of passengers on board in real time, helping the citizens better plan their travel. Both commuters as well as institutions will be beneficiaries of this initiative. Some of the benefits are:

- Minimized waiting time of the passengers at Bus Stations/stops
- Option for selecting the bus as per the seat availability.
- Information on Passenger load on the specific route.
- Differently abled commuters, Senior Citizens, Women etc. can utilize the system more efficiently due to occupancy information.
- If buses are delayed, passengers can make informed decisions about taking alternative routes or modes
- Addresses safety concerns
- Improved passenger satisfaction and reduction in customer complaints.
- More effective planning and scheduling of the buses.

The Road Ahead

The widespread use of the IUDX platform will dramatically enhance the power of new data-driven services available to citizens and administrators, and also increase the speed at which these can be created. It is expected that the collateral benefit on the broader public and private sector eco-systems will be equally significant. As city administrators and private companies see the value of sharing their data, it is expected to create a virtuous cycle- more data will be collected and shared, which will enable new services to enhance the value of data collected, and so on.

In addition, the burden on governmental resources will be reduced as private companies see the advantage of participating in this data ecosystem. Instead of waiting for governmental action to address issues, the culture will shift to self-empowerment where private companies and even individuals will use ingenuity to create data-driven solutions from IUDX-obtained data, without complicated procedures and approvals. The ultimate beneficiary of all these developments will be the urban Indian citizen and the quality of life in our cities.

IUDX: Unleashing the Power of Data for Public Good