CITIZEN-CENTRIC DIGITAL LAND AND ASSET MANAGEMENT IN A GREENFIELD CITY DEVELOPMENT: CASE STUDY OF AMARAVATI

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Abstract

Smart cities across the world are deploying digital systems and infrastructure, that is helping achieve various objectives on efficiency, transparency and in general, improved governance. However, we posit that digital systems should be developed to leverage on the density that cities garner and enable a sharing / access economy in addition to the close monitoring of key performance metrics for the city. In order to achieve the same, critical assets of the city – such as land, the built environment as well as the IoT infrastructure be managed digitally by systems that support the pressing challenges and opportunities emerging in cities. Amaravati, a greenfield capital city that is being developed by the Government of Andhra Pradesh is taking lead in deployment of various technologies to streamline its efficiency of operations whilst keeping the citizen at the center of such activities. Against this light, several initiatives such as a Citizen mobile application, blockchain deployment for land registry, development of a digital twin for the city, implementation of BIM and 3D City modelling all emerge as an array of best practices that cities can learn from. However as we move into the future, it is important to note how various data sources and applications converge in a manner that positively and systematically drives city outcomes – and it can only be achieved by design and policy. This paper delves into the details of the initiatives and how cities can be prepared for the future of digital asset management, as it unfolds in Amaravati.

Key Words: Amaravati, Andhra Pradesh, Smart cities, blockchain, asset management, urban platform, city data management, sharing economy, performance management

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The rise of urbanization, and along with it, smart cities

According to the 2014 United Nations (UN) World Urbanization Prospects report (United Nations, 2014), more than half of the global population now live in urban areas, and an additional 2.5 billion people are predicted to move to cities by 2050. Due to urban concentration, people's living conditions have been impacted by increased traffic jams, carbon dioxide, greenhouse gas emissions, and waste disposal. To cope with these crises, cities are focusing on modern technologies as well as aiming to reduce costs, use resources optimally, and create more liveable urban environment. (Jianjun, Jiaqi, & Kem, 2016)

The International Standards Organization, Smart Cities Strategic Advisory Group (ISO/IEC JTC 1, 2014) defines a Smart City as a city which;

- dramatically increases the pace at which it improves its sustainability and resilience,
- by fundamentally improving how it engages society, how it applies collaborative leadership methods, how it works across disciplines and city systems, and how it uses data and integrated technologies,
- in order to transform services and quality of life to those in and involved with the city (residents, businesses, visitors)

The British Standard Institute provides working definitions of Smart City vocabulary in their Public Accessible Standard PAS 180 (British Standards Institute, 2014):

"Smart cities" is a term denoting the effective integration of physical, digital and human systems in the built environment to deliver a sustainable, prosperous and inclusive future for its citizens.

The notion of "smart city" is a response to these problems; it has gained popularity over the past few years. Many cities define themselves as "smart" when they identify some of their own characteristics as being so (such as broadband connectivity, digital inclusion, and knowledge workforce). A common underlying fact is that these smart cities benefit from innovative applications of new kinds of information and communications technology (ICT) to support communal sharing (Agyeman and McLaren 2014).

What does ICT need to achieve in Smart cities?

Enabling a sharing or an "access" economy

Cities have long been posited as areas of increased density, enabling it to minimize the transport of goods, people and ideas. This density in turn brings in productivity, economic development and innovation required for cities to sustain. (Glaesar, Ponzetto, & Zou, 2015). The population density of urban living, cities are naturally designed to be sharing economies with consumption involving access to shared resources over asset ownership (Sundararajan, 2014). There are various ways of using modern technologies to create efficient economies and societies yet sharing is one of the most important characteristics of smart cities (Agyeman & Mclaren, 2014).

The sharing economy can be defined as an economic/social model that broad sectors of the population can employ to collaboratively make use of under-utilized assets, in which supply and demand are interacting for the supply side to directly provide products/services. On the supply side, individuals can offer things such as short-term rentals of their idle vehicles, or spare rooms in their apartments or houses. On the demand side, consumers can benefit from renting goods at lower cost or with lower transactional overhead than buying or renting through a traditional provider (The Economist, 2013).

The sharing economy has created a number of opportunities for smart cities in terms of improving asset utilization and effectively reducing transaction costs and waste. Improving the use of assets implies numerous positive consequences, for instance, energy saving and congestion decreasing. On websites, people can find rooms to stay in (Airbnb), as well as for using tools (UrbanClap), cars, bikes (ZoomCar), and on-demand taxi services (Uber). These websites unlock the value inherent in sharing spare resources as two-sided platforms, and offer many advantages to attract the two groups via network effects (Eisenmann, Parker, & Van Alstyne, 2006).

The sharing economy is driven by enabling technologies of digital connectivity, which provide the foundation of these innovations in the sense that it allows immediacy. The Harvard Business Review suggested that the correct descriptor for the sharing economy in the broad sense of the term is "access economy". The authors write, "When 'sharing' is market-mediated—when a company is an intermediary between consumers who don't know each other—it is no longer sharing at all. Rather, consumers are paying to access someone else's goods or services." (Eckhardt & Bardhi, 2015)

Enable operations management and performance measurement

It is not news that there is an astounding increase in the data that is generated in cities. Estimates suggest that there could be 50 billion IoT devices in the world, in just 4 years (Nordrum, 2016). In the past few years we have generated more data than the cumulative of all of humankind put together. This data provides an immense opportunity for city leaders amongst others to deliver substantial more value by deploying digital technologies.

Cities have now widely now been accepted to be in the business of "public good". The choice of performance metrics for a city varies from city to city depending on its aspirations and context. As urbanization sweeps across the globe, terms such as quality of life, wellbeing, livability and happiness are increasingly used to measure the performance of cities and countries. A recent report records 300 urban indices, globally, mainly dealing with objective metrics (JLL, The Business of Cities, 2017). Agencies like Mercer rank cities based on "quality of life" to inform private industry and their global workforce. More recently, urban metrics have been broadened to include metrics of subjective wellbeing as illustrated by the Santa Monica Wellbeing Index. More recently, there is increasing interest in measuring citizen well-being and happiness in cities (Prabhu, 2018).

Performance metrics support cities in making them and their private stakeholders more competitive, support innovation, improve efficiency, increase transparency, ensure affordability and other key goals. These measures then support the city governments to undertake necessary infrastructure investments as well as policy interventions to improve the quality of life and remain competitive. "Nudges" - measures that may not cost the Government or its stakeholder any substantial investment, have also been widely popular in ensuring change in the right direction, for cities. (Bousquet, 2017). A representative lifecycle of how such monitoring can affect city design and project execution is illustrated in Figure 1. Lifecycle of city design and project execution.

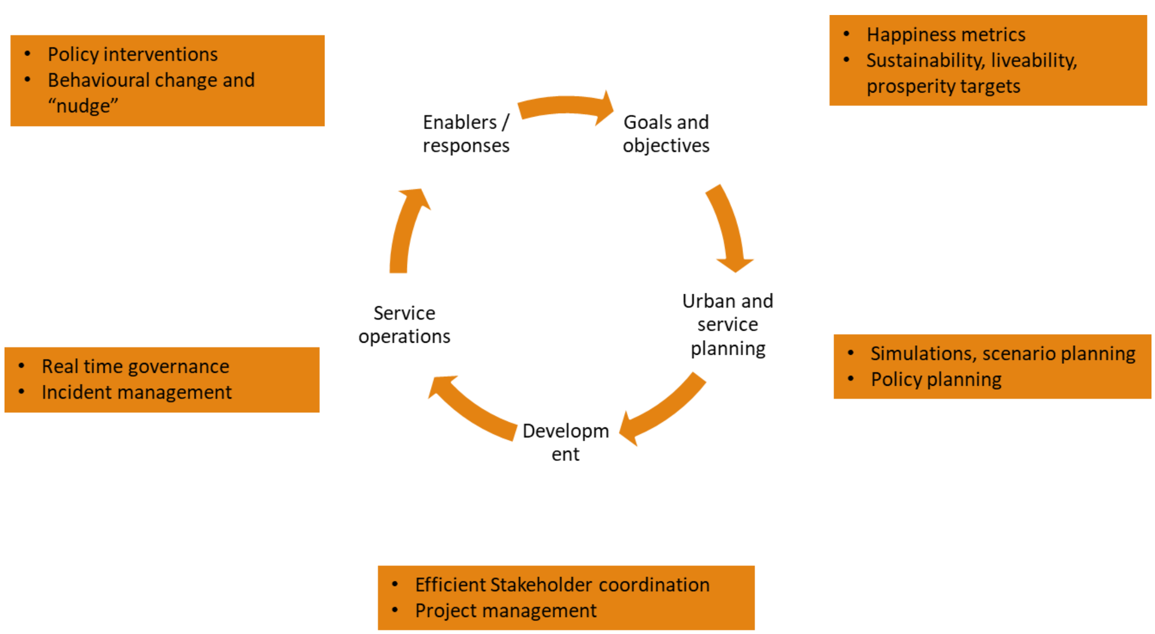

Figure 1. Lifecycle of city design and project execution

To realize the utility of data for measuring and improving their performance, cities are increasingly setting up "platform" for data to be collated, standardized and used by a wide set of stakeholders for their use. A survey by the European Innovation Partnership in 2015 listed that only 30% of the cities in Europe had invested in a platform. Constraints included poor knowledge of the domain, getting silos in a city to work together and budget constraints. Fast forward to 2018, over 50% of the cities have an operational platform. This indicates fast movement in the space, with the top motives being (1) improved efficiency and effectiveness (2) co-create services with business and citizens (3) stimulate entrepreneurship and innovation. (Colclough, 2015).

Assets in the context of a city

In the context of cities, to realize and enable the objectives of creating a sharing economy as well as performance measurement, it is critical to ensure the availability of data. Data are linked to assets, and citizens / entities, and it is important for the management of these assets to be such that the advances in digital technologies benefit both – assets as well as the citizens / entities. Against this light, we explore land management, management of the built environment as well as data sources linked to sensors and other data sources involving the Internet of Things (IoT). These data sets – briefly the GIS (Geospatial Information systems), BIM (Building Information modeling) and IoT (Internet of things) encapsulate a substantial portion of the assets in a city.

Land management

According to a widely accepted definition first put forth by the United Nations Economic Commission for Europe, land administration includes "the process of determining, recording and disseminating information about rights, value and use of land." In most developing economies, registry and cadastral systems that manage property rights are expensive to develop or configure, require relatively expensive hardware and software technology which needs to constantly be maintained (and budgeted for) and require technical specialists to administer. These systems often haven't proven to be sustainable, regardless of whether they are built on open source or proprietary software. (Anand, McKibbin, & Pichel, 2017)

Specifically, in India, land records maintained by the authorities are primarily used for fiscal purposes. The function of providing proof of title is purely ancillary to the purpose of collecting land revenue. Registration only puts an agreement between two parties on public notice but says nothing about the legal validity of the underlying transaction. This leaves titles secured through registration open to challenge in the courts of law. (Bal, 2017)

The Indian judicial system is currently buckling under the weight of a three-crore case backlog, 70 percent of which pertain to disputes regarding land or property (Daksh India, n.d.). Registrars will register any instrument received without checking its validity in the absence of countervailing claims. The Registration Act, 1908 does not require vetting the validity of documents and transactions.

Due to a lack of coordination between the various nodal agencies handling land records, the information registered is not standardised. This leads to ambiguity in terms of the nature of rights being transferred by the transaction and the boundaries of the land being transacted. Further, records are not updated promptly. Thus, they rarely reflect the true nature of ownership of a particular parcel of land. A report of the CAG showed that there was a backlog of some 124,325 cases for registration of property in 2015.

The current system is rife with corruption. Experts estimate that each year, USD 700 million in bribes are being exchanged at registrar offices across the country. The system has also led to the proliferation of an informal credit sector. Most poor farmers in India, due to a lack of formal title to their land, cannot use it as collateral against a credit transaction. As a result, formal credit institutions are inaccessible to most farmers, leaving them at the mercy of informal moneylenders.

Built environment assets

Cities across the world are increasingly developing “digital twins” – digital replicas that capture the GIS and built environment of cities in one platform to be able to undertake planning, simulations and various other applications at a city-scale. This digital replica of the city, is progressively informed by the real city, through real-time spatiotemporal data from infrastructure and human systems. The digital twin city, cognizant of the city’s infrastructure performance, human dynamics, their interdependencies and interoperability, and their fluctuations in time and space, is progressively able to anticipate changes of state in the systems and predict possible future behaviors. The predictive conduct of the digital twin city relies on the real-time and aggregated historical performance of the human-infrastructure systems. (Mohammadi & Taylor, 2017). Additionally, irrespective of the current state of the city, a digital twin city can simulate what-if scenarios in the system and anticipate emergent behavior. This helps analysts understand how cities equipped with smart technologies will likely perform under various economic, environmental, and social conditions, and identify the drivers of possible disruptions. (Anthopoulos, 2017). A few cities that are experimenting with Digital twins include Atlanta in the USA (Mohammadi & Taylor, 2017), Singapore (Wall, 2019)and Rennes in France (Doyle, 2019).

The digital twin for cities has its origin in "Building Information modelling", which has been around for a decade, although evolving in its definition and capabilities. The National Building Information Modeling Standards (NBIMS) committee of USA defines BIM as follows: "BIM is a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life cycle; defined as existing from earliest conception to demolition. A basic premise of BIM is collaboration by different stakeholders at different phases of the life cycle of a facility to insert, extract, update or modify information in the BIM to support and reflect the roles of that stakeholder (NBIMS, 2010)."

Although developed at a building scale, recent developments have now integrated of BIM models along with city data through the development of CityGML. By providing a core model with entities which are relevant to many disciplines the city model can become a central information hub to which different applications can attach their domain specific information. Information exchange between different disciplines can then be aligned with the objects of the city model. (Kolbe, 2009)

IoT and other data source assets

A smart city is equipped with different electronic elements employed by several applications, like street cameras for observation systems, sensors for transportation systems, etc. IoT devices are now ever pervasive, with multiple use-cases have been identified and implemented for IoT devices, in areas of Smart homes (with building management services), Smart energy, Smart traffic management and multiple other fields. IoT devices are not just owned and operated by public agencies, but the number of privately owned devices today far exceed the public sensors. As of 2011, the number of devices today is more than the number of people in the world. (Gubbi, Buyya, Marusic, & Palaniswami, 2013) Consider for instance, an metropolitan urban dweller owns a mobile phone, wearable devices such as fitbit, smart watches and so on.

IoT-driven services generate big amounts of real-time data. Besides the need to properly justify and plan the large investments in IoT solutions (by carrying out extensive impact, risk and cost-benefit assessments, which are not trivial tasks), other challenges facing smart cities and smart-cities-to-be include how to make sense and best use of such 'big data', while preserving citizens' privacy and data security. Cities can only be really 'smart' if they have in place the necessary intelligent, robust and reliable functions to integrate and synthesise these big data and filter out any unwanted 'noise' for the purpose of improving city efficiency, equity, sustainability and quality of life (Boulos & Al-Shorbaji, 2014).

What is blockchain?

Blockchain is a peer-to-peer distributed ledger technology which records transactions, agreements, contracts, and sales (Christidis & Devetsikiotis, 2016). The Economist describes blockchain as "the trust machine," indicating that it takes care of trust issues between individuals (The Economist, 2015). In other words, the economic system, which is built on blockchain technology, runs without people, thus making a transaction "trust-free." Historically, trust has underpinned business, often involving a reliable third party, which is expensive. Blockchain technology provides a viable alternative to eliminate intermediaries, thereby lowering operational costs and increasing the efficiency of a sharing service.

A few capabilities of blockchain is summarized below;

1. Blockchain technology enables people to access the records of every transaction they make, as it permanently records transaction history at every node of the blockchain
2. Blockchain stores some amount of information in them – which it provides immutability and proof against tampering. Any change to the information regenerates a hash-value which can be validated against
3. Blockchain operates a distributed operating model in which nodes, consisting of computers store complete or partial copies of the database, thereby making tampering difficult unless done across more than 51% of the network (Kamanashis & Vallipuram, 2016)
4. blockchain transactions are recorded using public and private keys (i.e., long strings of characters that people cannot read); thus, people can choose to remain anonymous to protect their privacy while enabling third parties to verify their identity (The Economist, 2016)
5. blockchain technology enables business transactions with strangers without the need for a trusted intermediary, allowing contractual promises to be enforced without human involvement.

As there are many variants of the technology, some of the above-noted features may not be present in all implementations. For example, distributed ledger technology (DLT) is closely related to blockchain technology, and sometimes used as a synonym for it. Many DLTs use proprietary software code; are permissioned (i.e., not publicly accessible like the Bitcoin blockchain); are under the central control of one organization as opposed to having a decentralized governance structure; do not chain transactions together in blocks; and do not employ an underlying token – and yet they are still associated with blockchain technology. In all of the variants of blockchain technology, the system designers make trade-offs among levels of trust, incentives, and efficiency, with concomitant impact upon the operation of the resulting blockchain solutions. (Dinh, Wang, Chen, Liu, & Beng, 2017)

Building digital systems for Amaravati

Background

Amaravati is the greenfield capital city of the state of Andhra Pradesh in India. It is India's largest greenfield urban development venture that took off in 2015. In one of the largest land pooling schemes undertaken in the world, over 28,000 land owners voluntarily pledged their lands for the development of the 217 sq.km city, which will hold a population of 3.5 million over the next 35 years.

Given the strong competence of the state government on adoption of digital technologies, the nodal agency for the city's development – the Andhra Pradesh Capital Region Development Authority (CRDA) was tasked with the requirement to ensure complete digital service enablement for all aspects of the city services and operations. The greenfield nature of the project enabled an excellent opportunity for the implementation of cutting-edge technologies without the often-complicated change management processes involved in the transitioning from incumbent systems. These technologies as we assess, have enhanced efficiency of operations, increased security, brought about transparency and trust in the Government.

The vision

Amaravati wanted to be completely digital in its operations, right from its very inception. Given its nature as greenfield city, Amaravati had the unique opportunity to adopt cutting edge practices across all its functions. Using a technological platform, Amaravati could achieve increased efficiency and transparency, adopt and fuel innovation in the city's operation and most importantly co-create with the existing citizens and businesses. The digital initiative was recognized as one that would achieve multiple objectives - on efficiency, economic development and civic engagement, providing it with utmost importance alongside the development of the basic infrastructure such as roads, water, power and other related systems.

It is however important to note the function of technology as an "enabler" in the overall objective of the city government, and not be dictated by the technologies and industry trends. Whereas initial metrics of city performance included purely economic activity such as GDP, it has hence evolved to measure livability and quality of life. Capturing wider subjective citizen sentiment in the measure, Amaravati is adopting "happiness" (or "well-being") as its core metric of performance.

The stakeholders

In the context of Amaravati, we identify three stakeholders who are the central focus to this paper, who we categorize as the "land-owner", the "developer" and the "user".

- The "land owner" owns land parcels within the city of Amaravati, and through the Land Pooling scheme, exercises his options on the number and sizes of plots in the newly prepared masterplans, for which he has provided his suggestions and inputs. Subsequent to receiving the reconstituted plots the land owner also have the provision to sell / lease their land plots to other private developers.
- The "developer" constructs housing, commercial and other uses in the land that he owns / has rights to develop on. For this he designs, seeks approvals and constructs the property. Depending on the use, he may lease it out, or operate on his own.
- The "user" consumes utility services such as water, power and other requirements, utilizes the city's mobility systems and the various human services such as security, education and healthcare.

In the following section, the initiatives that Amaravati has successfully executed, and how it plans to achieve the vision of a setting up a Citizen-centric digital land and asset management system.

Participatory Planning through the Land Pooling Scheme

Amaravati undertook a Land Pooling scheme, wherein land-owners voluntarily provided their land to the Government for the capital city development. In return, the land owner received a proportionate amount of the land in a developed neighbourhood. Such a mechanism ensured that the land owners continue to remain as partners in the development as opposed to Land acquisition where farmers are given a one-time compensation to surrender and provided rehabilitation. The Land Pooling Scheme followed by Amaravati was one that ensured multiple consultations with the land owners, incorporating and revising the benefit schemes and masterplans based on their feedback to arrive at a scheme that the community "owned" as their own. (Cherukuri, 2018). A few digital initiatives that led to the rapid completion of this participatory scheme is provided below.

1. Entering into agreements with the land owners

   The process of land assembly and reconstitution involved a voluntary land pooling scheme, from over 28,000 land owners and covering over 38,000 acres having varied land holding sizes and categories. It was important to have a robust system in place to manage the complicated ownership types and pattern, calculate the benefit sharing packages and monitor its implementation. The overwhelming response resulting in successful land assembly of 33,000 acres comprised verification of millions of data records, which was made possible through an inter-operable data model across revenue, registration and CRDA departments.

An IT application was developed for managing the LPS process and its related activities. The applications enabled and streamlined all required documents and agreements required as per the scheme. All the objections, suggestions and grievances were also received and managed through the system. The system helped maintain a comprehensive list of owners, plot details and other related information, which was linked with the country's unique identification number, Aadhar. This helped ensure that no duplication had occurred especially with regard to fund disbursement for pensions and annuities. All the details of the scheme, including the plots, the benefits provided till date and so were made available on the APCRDA website.

2. Providing benefits

   APCRDA developed an IT solution to automatically calculate the financial compensation that a farmer would receive for his land contribution. This was developed not just for the land owners, but also the landless farmers (project affected families) belonging to the capital city area, as they were also provided with pensions for 10 years. To cater to this requirement of making monthly payments to all verified land owners, a Central Fund Management System was set up, which automatically transferred the funds online. This system uses a highly secure PKI Infrastructure for this online fund transfer mechanism, hosted on cloud infrastructure.

3. Participatory and consultative planning

   During the land reallotment process, the land owners were provided with the option to choose the number of plots and plot sizes that he/she wanted. The land owners were also given the option to join with other land owners and opt for larger plots or multiple small plots. This choice provided over 4,000 options, which would not have been possible to be incorporated without the use of GIS and IT systems specifically developed for this purpose. Additionally, the options provided by the land owners were with vastu (local planning customs) to generate neighbourhood layouts that met high standards of liveability.

4. Plot reallotment

   An ICT system was developed to allocate plots between land owners in a "randomized" fashion. This was undertaken through a public lottery process where the population of the village along with senior Government officials would witness multiple trial lotteries, following which the final allotment was done. Once the final allotment was done, all the land owners received SMS alerts providing them with plot codes in the masterplan.

5. Grievance redressal and communication

   APCRDA also developed "Mana Amaravati", a one-stop mobile application for citizens of Amaravati on all the city services operational till date, a two-way communication channel between citizens and government was put in place. The status of all the benefits that are eligible under the user's Aadhar (unique ID) login were provided, including annuity payments, pensions, health, education and other schemes. All grievances related to the scheme was addressed in 48 hours thereby reducing the necessity for the citizens of Amaravati to visit the offices and follow-up on their grievances.

Blockchain enabled Land management system

After the successful completion of the Land Pooling Scheme, Amaravati had near complete database of land records, linked to their GIS coordinates, ownership details and other related information. All the land owners received Land ownership certificates that provided them with online links to access details of their plots on an online GIS system.

Subsequently, all the land records including the GIS as well as the relevant ownership certificate and documents were linked to a scalable Blockchain platform called "Zebi Chain". All the plots within the city were linked to the blockchain with the "plot IDs" as identified, and all transactions linked to every plot permanently kept a record of, in the blockchain registry.

All involved sellers/buyers were provided with a digital file representing the agreement of ownership of the real estate, mortgage deeds and the transaction process. The QR code embedded in every certificate redirects the user to a webpage which validates whether the said registration is currently available for sale, or is invalid.

APCRDA Land Registry application was tightly integrated with other departments like the state's IT portal and the registrations department, the nodal agency in the state responsible for maintenance of the land records. WebAPI were deployed to ensure integration of data between AP Online and the registration department, ensuring the validity of every transaction that is undertaken.

The Flow of data in Registry land records in Blockchain in three stages:

- Initially the new / first time registration will be in Insert Stage (GIS Data flows from lottery). Separate API is designed to handle the insert record, block chain will treat this as new record and update in the database with minimal validation.
- Mutation data from Registration dept. of existing land records: Registered data inserted into AP Online DB by using webservice at Registration dept. And these records automatically updated at GIS DB using WEBAPI, the same records to be updated/replaced corresponding attribute data in Blockchain db by calling Blockchain API's. The blockchain then subsequently maintains a time-stamped record of every transaction on every plot of land for future reference.
- Deletion of Land Records: These records will be recorded at field level after user requests, WebAPI is running at APOnline db to update/delete records at GIS database and the corresponding attribute information will be updated in Blockchain db by running WebAPI at GIS apps.

An attempt made to tamper the data on the blockchain which is not validated through the appropriate API service is rejected by other nodes in the blockchain, thereby effectively avoiding any tampering.

A few benefits of this technology are the increased processing efficiencies that reduce the cost of land transaction processing; reduction in errors during the recording process; prevention of title fraud; added levels of security, auditability and transparency; data archiving, and lower levels of vulnerability to natural or man-made disasters.

Planning, development and monitoring of the built environment

As an overlay on the existing GIS system that APCRDA has implemented, a "3D City platform" that can support the creation of a 3D model of the city in its current state as well as the future holds great potential to undertake simulations, collaborations and create marketplaces. The backbone of this platform is enabled by the BIM data availability of public infrastructure as well as BIM data of all private development, mandated by the BIM-based building permit system. The possibilities in terms of the lifecycle of the built environment on the platform is depicted in Figure 2.

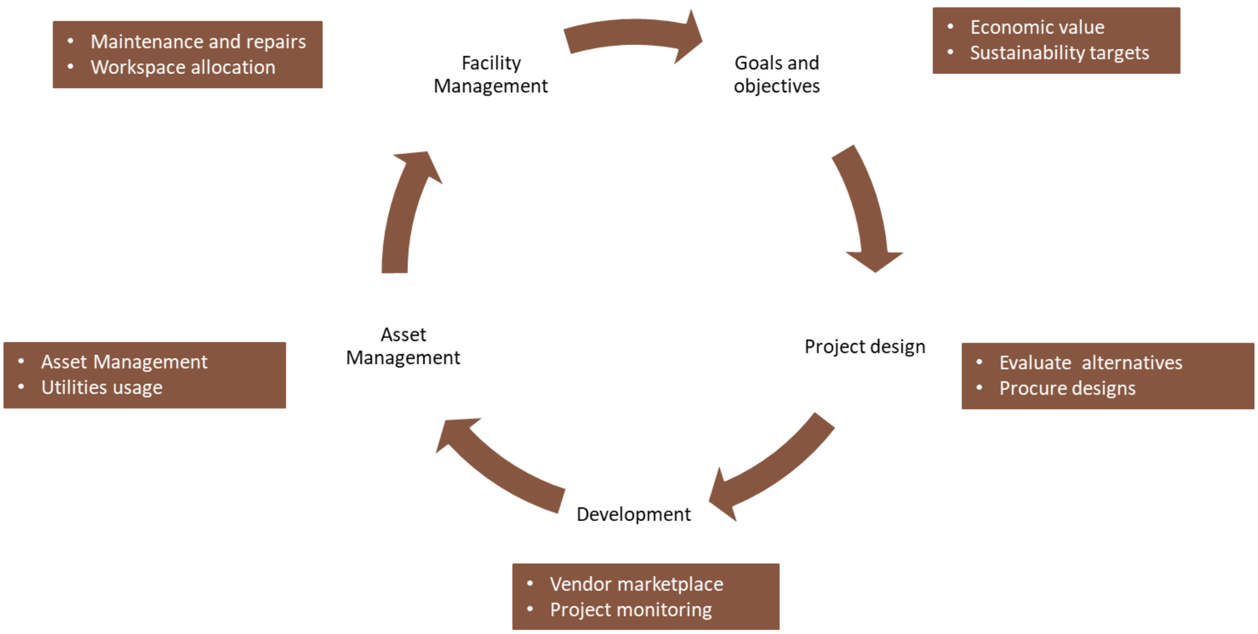

Figure 2. Lifecycle of digitally enabled built environment

1. Urban planning

   The city masterplan was designed in a data-rich digital environment consisting of satellite imagery, topography and LiDAR maps. The designing of the masterplan in such an environment and subsequent iterations reduced the physical displacement required by 90%, from 4,000 to 400 households.

2. Simulations

   In the preparation of the masterplan, simulations were performed to evaluate design options on the basis of micro-climatic conditions, walkability, sustainability and other metrics. Based on these calculations, the targets for the city were validated and implementation plans are being developed. The simulations were undertaken on ESRI ArcGIS engine with 3D modeling capabilities. In an effort to keep costs down further, modules for masterplan revisions, scenario planning and such modules are now being developed in open-source software.

3. Construction planning and monitoring

   Currently in Amaravati, over $8bn of works are under construction. These include buildings over $1.5bn, and the remaining consisting of integrated utility development of roads, water supply, sewer lines, power, ICT and others. Given the extent of the development across a large extent, multiple contractors and project management teams have been set up. To coordinate between the teams, Building Information Modelling has been helpful in detecting clashes and preparing schedules.

4. Marketplace for land transactions

   To enable trade of plots by the farmers, the GIS system and the land management systems was integrated into a marketplace on a mobile application. The application provided an Aadhar (Unique ID) based login, based on which any land owner's plot can be notified for sale and lease to the wide investor community. An internal survey showed that the creation of marketplace enhanced the number of leads that the land owners received by as much as 100%.

5. Regulations and development control

   The state has pioneered the implementation of online building permit system. As the city begins to develop, the city implemented an automated BIM-based building permit system, making it more efficient to enforce building bylaws and urban design principles of the city. Drones are deployed to measure the dimensions of the buildings against the approvals accorded to identify any variations. The BIM models moreover facilitate forecasting the infrastructure demand for the city, enable a wide range of urban planning functions such as micro-climatic simulations, aid in emergency response, sustainability and performance monitoring. Building Permissions are provided instantaneously, as opposed to the 1 week processing time taken by Municipal corporations in the state.

6. Marketplace for city services

   In line with the creating an "access economy" in the city, the Government has in the process of developing a digital twin that is linked to a citizen portal. Through this portal, the citizens would be able to procure various city services – such as procurement of architectural models for construction, lease of housing, provision of utility services to properties and so on. The vendors would greatly benefit from the availability of asset data within the system, which will help tailor solutions. For example, it could be possible to view various painting options for your house on an application thanks to the availability of BIM, and directly measure and order the required amount through an online service.

7. Technical and facility management systems
   After the building permit is issued, construction completed and occupancy has begun, the building will require facility management systems. These systems are increasing in adoption in large business parks for the maintenance of AMCs, technical repairs, space management, consumption management and so on. However the availability of these services for smaller scale residences and commercial properties are difficult, and it is expected that the platform that Amaravati is now developing would be able to create the necessary economy of scale to make such tools affordable and available.

Service planning and operations

Through the deployment of sensors including network sensors in power, water, etc; CCTV cameras, environmental sensors across the city, predictive maintenance and efficient operations are assured. Additionally, through the integration with other sources of data, including publicly available data, healthcare systems and such systems, it is estimated that Amaravati would be able to measure its progress towards achieving the targets it has set for itself on "happiness".

An integrated Command and Control Center is currently under development to provide advanced analytics and business intelligence to aid the prediction, and in the case of an incident, tools to enable troubleshooting and collaboratively drive solutions. Analytics from the services associated with consumption would also be provided to the citizen to create awareness of the possibilities to cut down based on best practices that can be undertaken, through nudge mechanisms.

Future of asset management

Smart city framework – an Urban platform

It is widely touted that the future of managing the complex relations between data and its utilization by applications would be facilitated through an "Urban platform" that would encapsulate various kinds of data – sensors, social media, mobile devices and a myriad of other means. As defined by the British Standards Institute in PAS 181, an urban platform is defined as below:

Urban Platform': is the way of describing a logical city data architecture that brings together and integrates data flows within and across city systems in a way that exploits modern technologies (sensors, cloud services, mobile devices, analytics, social media etc). An urban platform provides the building blocks to enable cities to rapidly shift from fragmented operations to include predictive effective operations, and novel ways of engaging and serving city stakeholders; It has the potential to transform, in a way that is tangible and measurable, outcomes at local level (e.g. increase energy efficiency, reduce traffic congestion and emissions, create (digital) innovation ecosystems, efficient city operations for administrations and services).

An urban platform could, arguable enable the sharing / access economy, help in the smooth operations of city services, and enable performance monitoring. A conceptual framework for the urban platform is provided in the illustration below in Figure 3, as adopted from ISO 37108:2018 (British Standards Institute, 2018).

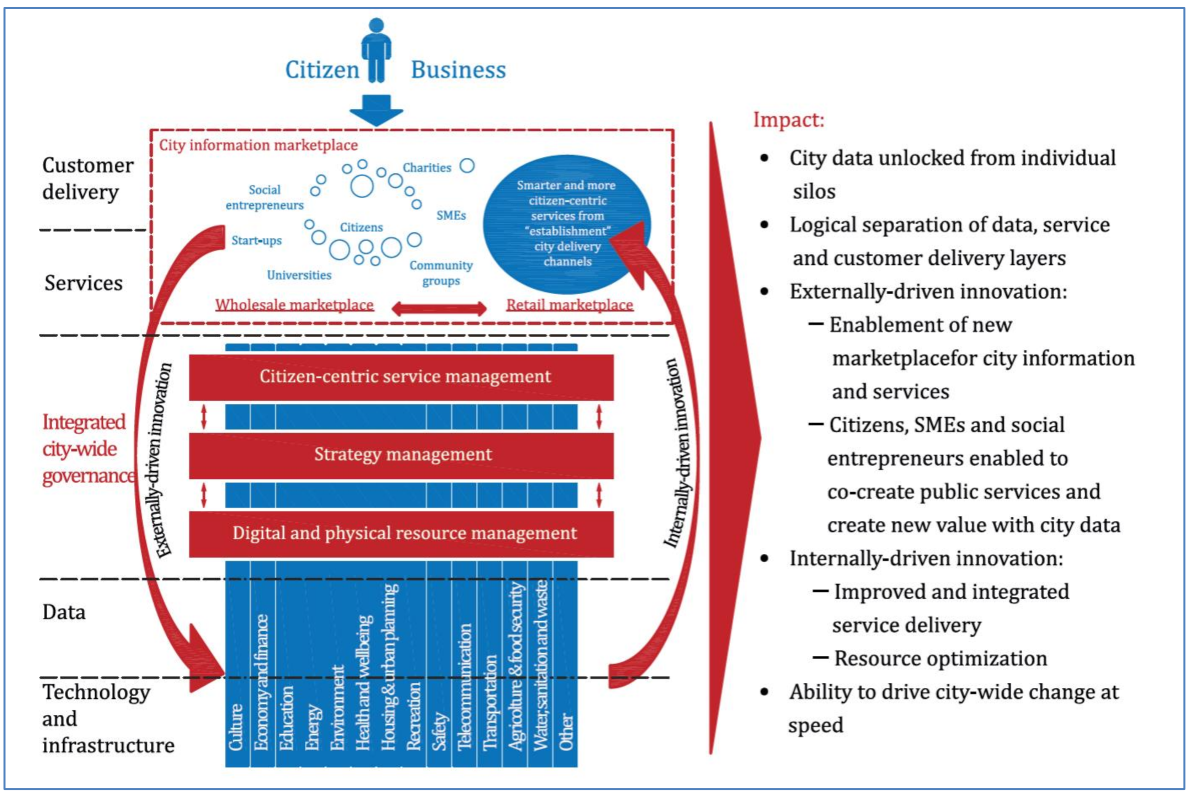

Figure 3. Smart city conceptual framework

The creation of such an urban platform however, is an initiative that few cities have made progress towards, although the intent by city governments have been established previously in the context of European cities. Even if such an all-encompassing urban platform were to be implemented, it would only be as useful as the data and the applications that operate on it. Data could be of the 5 classes below, and a few of them are enlisted below:

1. Sensors / IoT data
2. Open data – includes data made available by public agencies including GIS, and other relevant city statistics
3. Firewalled data – data from various city services that run city / utility services
4. Commercial data – data that is gathered and held by commercial entities for their own business interests such as telecommunication companies
5. Social media – sentiment of citizens in a city as talked about on Facebook, Twitter, etc

With recent trends, there is pressing evidence on the increase of data of critical city information that is being operated and kept as commercial data, away from city authorities. A case study worth pointing out is the riverfront precinct on Toronto where the City Government in a joint venture with an Alphabet company – Sidewalk labs are developing a fully smart, digital and IoT embedded city. However after recent events in the Silicon valley on data privacy and security, the citizens are increasingly questioning the business model of the precinct, and specifically the monetization of citizen's data (Bliss, 2018).

A similar trend is also emerging for multiple services that initially commenced operations within cities as a service, but are now evolving into platforms and of more concern, data monopolies. Uber for instance, with its increasing use by urban commuters have increasing amounts of data, which is now fueling the roll-out of additional mobility services under the same platform. These systems often leave cities without the required data to revamp its mobility systems if it were to, leaving it at a disadvantage.

However, for assets that are owned by cities, there are success stories for how cities have been able to create an access economy. A good use case where data standards and a market place have delivered value in the Energy sector is of the Green Button Alliance. In Toronto, Canada, the green button alliance created data standards for all smart meter devices and utility companies. A marketplace was subsequently created where customers could choose to share their energy consumption data with third party applications, which resulted in the creation of over 24 applications in 2 years, with over 6,000 installs.

Blockchain could play a critical role in ensuring data governance as the greenfield city of Amaravati progress, as every asset in the city is linked to a blockchain – linked to the property or a citizen. This provides citizens more control over their own data and its use. It also enables, through the smart contracts and trust relations that blockchain enables, the possibility that public agencies can access privately held data, so long as the citizens provide consent (and vice versa). The enforcement of such rights could be effectively undertaken with the deployment of blockchain. The 6Cs of data management for citizens is illustrated in Figure 4, as provided under the OASIS TGF (OASIS, 2013).

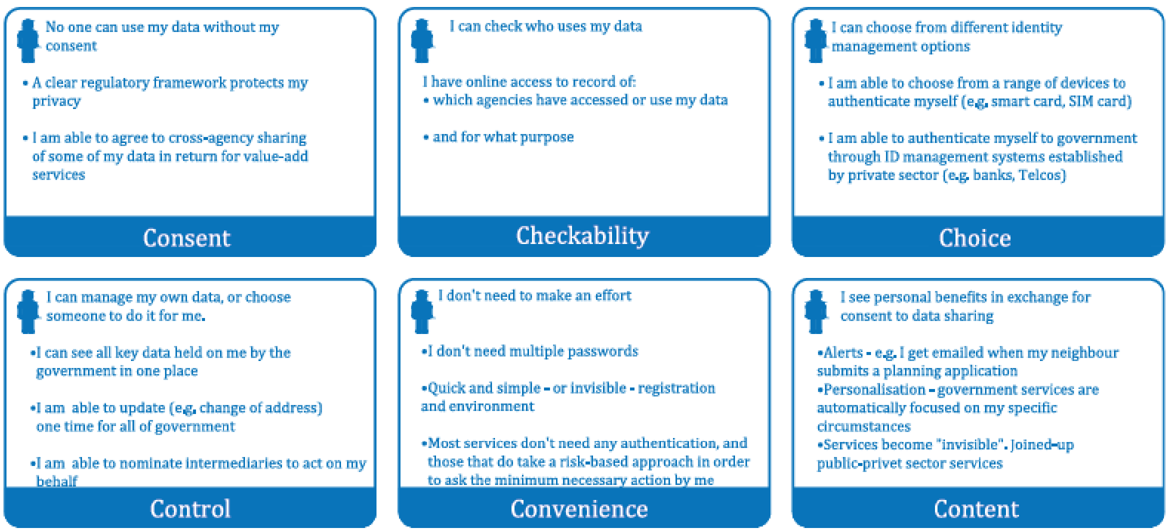

Figure 4. Data management principles

Creating an innovation eco-system

With the access made available for various forms of data to city departments, business and citizens – the potential of creating applications and "intelligence" using AI, Machine learning and similar techniques can substantially enable the creation of viable business models and of value for strategic planning.

As cities increasingly adopt digital frameworks to support their day-to-day service delivery and meet city objectives, there would an emerging market to tackle use-cases that are applicable to multiple cities. Creating an open marketplace where applications developed for one city can be easily deployed into other cities can create a strong impetus for applications to be developed.

Applications the can find a place for deployment on an urban platform could fall under any of the below two categories -

1. Those developed for specific requirements of the city authority, such as a
    a. Performance measurement framework against its key objectives
    b. Supporting effective service delivery
2. Those developed for meeting requirements of citizens, businesses and other stakeholders enabled by the data available on the platform

The applications in the first category would consist of various tools that would help inform for the cities, better planning, infrastructure demands and measurement against various KPIs. Assessment of solar radiation, wind flow analysis, micro-climatic conditions, accessibility of various plots from social facilities, traffic simulations and various other tools could be developed for the city.

It is also anticipated that there would be several applications that will be required to meet requirements of citizens, that will support him/her across every walk to life. Availability of timely information on public transport, access to public amenities and facilities is an important aspect for the city, so is setting up various services for tax collection, user charge collection, grievance redressal and so on. A lot of these applications will be developed by the city government and provided to citizens free of cost.

If a customer had access to his own energy usage data and was given insights on reduction of his power consumption, it is fair to assume that a business case proportionate to amount of savings that can be achieved exists. Similarly, a customer sharing healthcare data to a digital well-being application which provides insights on daily well-being could be of substantial value. The value of data intelligence varies substantially from market to market, and the platform can enable and create opportunities to monetize such intelligence.

Empowering the citizen or private entity with access of its own data also improves ease of catering to various service and product requirements that he may be looking to procure. With availability of BIM model of one's own house, shareable over an application, a third party vendor can easily assess requirements and install air conditioning, solar panels, carpets, furniture and many more, from the comfort of one's home.

Conclusion

As the city continues to develop, the city is creating a data-rich interoperable platform which can be used not just by the citizens and city administration, but the wider stakeholder community including architects, developers, contractors, businesses, academia and so on. While the benefits of data for the city administration is well understood for improved service delivery, the creation and upkeep of the underlying data required would only be possible with an approach that places and benefits the citizen at the core of such a system. Thanks to these initiatives, Amaravati performance measurement is now on metrics such as liveability, well-being, sustainability and inclusivity.

References

Agyeman, J., & Mclaren, D. (2014, Sept 29). *'Smart Cities' Should Mean 'Sharing Cities'*. Retrieved from Time: http://time.com/3446050/smart-cities-should-mean-sharing-cities/

Anand, A., McKibbin, M., & Pichel, F. (2017). Colored Coins: Bitcoin, Blockchain, and Land Administration. *World Bank Conference on Land and Poverty.*

Anthopoulos, L. (2017). Smart utopia VS smart reality: Learning by experience from 10 smart city cases. *Cities*, 128-148.

Bal, M. (2017). *Securing Property Rights in India through Distributed Ledger Technology.* Observer Research Foundation (ORF).

Bliss, L. (2018, Sept 7). *How Smart Should a City Be? Toronto Is Finding Out*. Retrieved from City Lab: https://www.citylab.com/design/2018/09/how-smart-should-a-city-be-toronto-is-finding-out/569116/

Boulos, M. N., & Al-Shorbaji, N. M. (2014). On the Internet of Things, smart cities and the WHO Healthy Cities. *International Journal of Health Geographics*, 13:10.

Bousquet, C. (2017, Feb 28). *Data Smart City Solutions, Harvard University.* Retrieved from Ten Ways Cities are Nudging for Better, Healthier Citizens.

British Standards Institute. (2014). *Smart Cities - Vocabulary.* British Standards Publication.

British Standards Institute. (2018). *Sustainable cities and communities - Guidance on establishing smart city operating models for sustainable communities.* BSI Standards Publication.

Cherukuri, S. (2018). Innovative and Inclusive Land Pooling Scheme for Developing a Sustainable New Capital City in Andhra Pradesh (Amaravati), India. *World Bank Land and Povery Conference.* Washington DC.

Christidis, K., & Devetsikiotis, M. (2016). Blockchains and Smart Contracts for the IoTs. *Special section on the plethora of Research in IoT, IEEE Access*, 2292-2303.

Colclough, G. (2015). *Urban Data Platform.* Retrieved from European Innovation Partnership on Smart Cities and Communities.

Daksh India. (n.d.). *Daksh*. Retrieved from Access to Justice Survey: http://dakshindia.org/access-to-justice-survey-results/index.html

Dinh, T. T., Wang, J., Chen, G., Liu, R., & Beng. (2017, Mar). *Blockbench: A Framework for Analyzing Private Blockchains*. Retrieved from https://arxiv.org/abs/1703.04057

Doyle, S. (2019, Jan 17). *Digital urban planning: twins help make sense of smart cities*. Retrieved from E&T: Engineering and Technology: https://eandt.theiet.org/content/articles/2019/01/digital-urban-planning-twins-help-make-sense-of-smart-cities/

Eckhardt, G. M., & Bardhi, F. (2015, Jan 28). The Sharing Economy Isn't About Sharing at All. *Harvard Business Review*.

Eisenmann, T., Parker, G., & Van Alstyne, M. W. (2006). Strategies for Two-Sided Markets. *Harvard Business Review: On Point*.

Glaesar, E., Ponzetto, G., & Zou, Y. (2015). *Urban Networks: Spreading the Flow of Goods, People, and Ideas.*

Gubbi, J., Buyya, R., Marusic, S., & Palaniswami, M. (2013). Internet of Things (IoT): A vision, architectural elements, and future directions. *Future Gener. Comput. Syst*, 1645-1660.

ISO/IEC JTC 1. (2014). *Smart Cities: Preliminary report.* ISO.

Jianjun, S., Jiaqi, Y., & Kem, Z. K. (2016). Blockchain-based sharing services: What blockchain technology can contribute to smart cities. *Financial Innovation*, 2:26.

JLL, The Business of Cities. (2017). *Decoding City Performance.* JLL.

Kamanashis, B., & Vallipuram, M. (2016). Securing Smart Cities Using Blockchain Technology. *2016 IEEE 18th International Conference on High Performance Computing and Communications; IEEE 14th International Conference on Smart City; IEEE 2nd International Conference on Data Science and Systems*.

Kolbe, T. H. (2009). Representing and Exchanging 3D City Models with CityGML. *3D Geo-Information Sciences*, 15-31.

Mohammadi, N., & Taylor, J. E. (2017). Smart City Digital Twins. *IEEE Symposium Series on Computational Intelligence*.

NBIMS. (2010). *National Building Information Modeling Standard.* Retrieved from http://www.wbdg.org/pdfs/NBIMSv1_p1.pdf

Nordrum, A. (2016, Aug 18). *IEEE Spectrum.* Retrieved from Popular Internet of Things Forecast of 50 Billion Devices by 2020 Is Outdated: https://spectrum.ieee.org/tech-talk/telecom/internet/popular-internet-of-things-forecast-of-50-billion-devices-by-2020-is-outdated

OASIS. (2013). *TGF-PL-Core-v1.0 Transformational Government Framework (TGF) Pattern Language.* OASIS Standard.

Prabhu, R. (2018). *Developing a Happiness Index: A Roadmap for Amaravati Capital City.*

Sundararajan, A. (2014). Peer-to-peer businesses and the sharing (collaborative) economy: Overview, economic effects and regulatory issues. *Written testimony for the hearing titled The Power of Connection: Peer to Peer Businesses*.

The Economist. (2013). The rise of the sharing economy. *Economist*.

The Economist. (2015). *The promise of the blockchain: The trust machine*. Retrieved from http://www.economist.com/news/leaders/21677198-technology-behind-bitcoin-could-transform-how-economy-works-trust-machine

The Economist. (2016). *The blockchain in finance: Hype springs eternal*. Retrieved from The Economist: http://www.economist.com/news/finance-and-economics/21695068-distributed-ledgers-are-future-their-advent-will-be-slow-hype-springs

United Nations. (2014). *World Urbanization Prospects.* The Population Division of the Department of Economic and Social Affairs of the United Nations.

Wall, M. (2019, Jan 18). *Virtual cities: Designing the metropolises of the future*. Retrieved from BBC News: https://www.bbc.com/news/business-46880468

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