Optimization of ICT Street Infrastructure in Smart Cities

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Abstract. Technology solutions are now helping the urban local bodies in Indian Smart Cities to make smart and effective decisions. With these technologies coming up there IoT devices can be seen making its place on urban streets. This paper focuses on the overall view of the ICT (Information and Communication Technology) components and its placement in the city at various locations on the streets. The research for ICT street infrastructure when deployed for upcoming smart cities would help in optimization of ICT street infrastructure and bring down the total life cycle cost in terms of the cost of ownership and the recurring expense for operation and maintenance, for the deployment in upcoming cities.

Keywords: Smart city · IoT · ICT · Street infrastructure · Optimization

1 Introduction

1.1 Smart City

There is no universally accepted definition for Smart City, Smart City has different meanings for different people in different countries. On a broader level, Smart Cities are the urban areas that utilize electronic data collection sensors to give and transfer information in order to manage the assets and resources efficiently in order to give better services to the citizens of the city [1]. Technology solutions are now helping the urban local bodies in Indian Smart Cities to make smart and effective decisions. Smart systems have become the key for providing citizen-centric services like traffic, health, safety, transit, etc.

Smart City projects are further divided into pan-city and area-based development projects. The research is focused on the Pan city ICT (Information and Communication Technology) projects in a smart city. All Pan city IT and ICT projects have two components; Hardware (Field devices, sensors, IoT devices and its supporting components) and software. Smart cities in India usually include following hardware components, CCTV, ANPR (Automatic Number Plate Recognition), RLVD (Red Light Violation Detection), ECB (Emergency Call Box), PA (Public Address), ATCS (Automatic traffic Control System), VMD (Virtual Messaging Display), Environmental Sensors, Smart Lights, PIS (Passenger information Screen) at City Bus stops,

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Supporting Infrastructure such as Junction Box, OFC (Optical Fibre Cable), Electric Meters, Poles, etc. All these hardware components form the basic components of the street infrastructure. They are installed on streets, which usually have just 12% to 18% of the land of the city.

"Smartness" doesn't come from installing smart devices on traditional infrastructure. It is using technology to analyse the data gathered, to facilitate decisions and help improving citizen services to enhance quality of life. Quality comes up with many dimensions, it includes everything from the air that citizens breathe to how they feel on the streets. There are dozens of smart sensors/devices installed on the streets, to sense & communicate the same to the command centres [2].

This paper focuses on the overall view of the ICT (Information and Communication Technology) components and its placement in the city at various locations. This shows the complexity due to the haphazard and unplanned ICT street infrastructure. It was noticed that the most advance cities need to improve a lot for its fundamental street infrastructure for all smart devices to function and achieve the larger goal of city operations.

2 Methodology

Research commenced with the background research, which helped derive the problem statement and research questions. This was followed by a literature review, a study of street design guidelines for different cities to understand the placement of ICT Street Infrastructure in cities. Case studies of various cities having different street infrastructure with IoT and ICT components were also studied. (Chicago, New York, Colombia & Pune). This was followed by primary data collection which involved site visits to various locations in the city. Interactions with various stakeholders were done to understand the complexity in implementation of ICT street infrastructure. Based on the data available from primary and secondary data collection, analysis was done of the ICT street infrastructure in the city. An in-depth study and analysis of current infrastructure was done to find the root cause analysis for its high CAPEX and OPEX costs. Based on this research, a modular pole was designed, and a pilot study was conducted at one junction in City A.

2.1 Problem Statement

The City Government (Urban Local Body) is investing huge quantum in ICT Street Infrastructure; however, this infrastructure becomes an integral part of day-to-day operations. Despite this aspect being so important in daily life, it is not organized and placed haphazardly. Hence it is important to manage the street infrastructure for better operations and cost-effectiveness.

2.2 Research Objective

- Understanding the Different ICT Infrastructure on Streets and Junctions
- Studying the implementation procedure for the street infrastructure in a smart city.
- Optimizing the ICT Street Infrastructure for O&M and cost-effectiveness.

3 Literature Review

The concept of Smart Cities can be looked upon as a framework for implementing a vision to help achieve the benefits of modern urbanization. The inclination to adopt the Smart City model is driven by the need to surpass the challenges posed by traditional cities, as well as, overcoming them in a systematic manner [3]. It is crucial for cities therefore to explore a shift towards adopting sustainable city development measures amongst all stakeholders, namely - Citizens, Businesses and the Government. City-level interventions to support the development of urban environments that enhance economic growth and enhance overall quality of life are more vital than ever, but need to be tailored to the historical, spatial, political, socio-economic and technological context of cities at different stages of urbanization [4].

As part of literature review, street design guidelines of Pune, New-York & Colombia were referred. It was found that most of the Indian cities don't have street design guidelines. Better Streets, Better Cities by ITDP (Institute for Transportation and Development Policy) & EPC (Environmental Planning Collaborative) helped to understand the principles of street infrastructure [3]. Streetlight policy and design guidelines by the Department of Transportation, District of Columbia helped to understand Methodology for change in street infrastructure [4]. Pre-Standardization study report, Unified, secure and resilient ICT infrastructure by Bureau of Indian Standards helped understand the standardization procedure adopted for the services [5].

AoT (Array of Things) in Chicago has essentially served as a "fitness tracker" for the city, measuring factors that impact livability in cities such as climate, air quality and noise. The node is created which contains all sensors and it can be mounted on a traffic pole or wall whichever is feasible. Department of Transport Chicago is currently installing it on Light pole and data is hosted on open data portal for private companies and students to do research [6].

For all cities, the task was to fix all the elements to the street template so that it defines a unique street, based on the requirement, size, location and demand. Principles for the street design guideline were Public Safety, Environment, Design and Aesthetics. Cities like New York have a street design guideline describing all different elements that can come to a street [7].

"How to design and maintain a city is critical to creating a sustainable ecosystem—one that provides not only for today's needs but for the needs of future generations, and one that takes not only humans into account but all life. To achieve this goal, cities must end the 'business as usual' approach and become caretakers for both the people they serve and the environment in which they live" [8].

4 Analysis of ICT Street Infrastructure

4.1 Different ICT Infrastructure on Streets and Junctions

Smart cities in India usually include following hardware components, CCTV, ANPR (Automatic Number Plate Recognition), RLVD (Red Light Violation Detection), ECB (Emergency Call Box), PA (Public Address), ATCS (Automatic traffic Control System), VMD (Virtual Messaging Display), Environmental Sensors, Smart Lights, PIS (Passenger information Screen) at City Bus stops, Supporting Infrastructure such as Junction Box, OFC (Optical Fibre Cable), Electric Meters, Poles, etc. All these hardware components form the basic components of the streets in the city. The data collected by these components is collected at the Integrated Command and Control Centre (ICCC) of the city. At ICCC this data is analysed and based on the data further actions are decided by ULB (Urban Local Body).

4.2 Comparative Analysis of Street Infrastructure in Five Different Smart Cities

A study of the street infrastructure across the different smart cities in India was done based on the smart city proposals submitted by the respective cities. It was observed that City A had the maximum street infrastructure, as seen in Table 1. To understand in-depth the ICT street infrastructure in city a detailed case study was done for the infrastructure installed in the City A [11].

Table 1. Comparative analysis of street infrastructure in smart cities

Street infrastructure	City A	City B	City C	City D	City E
Optical fiber	Yes	–	–	Yes	Yes
CCTV	Yes	Yes	Yes	Yes	Yes
ANPR	Yes	Yes	Yes	Yes	Yes
PA system	Yes	Yes	Yes	Yes	Yes
ECB	Yes	Yes	Yes	Yes	Yes
Env. sensors	Yes	Yes	Yes	Yes	Yes
ATCS	Yes	Yes	Yes	Yes	Yes
VMD	Yes	Yes	Yes	Yes	Yes
Smart light	Yes	Yes	Yes	–	–
Smart roads	Yes	Yes	Yes	Yes	Yes
Smart POLES	Yes	–	Yes	–	Yes

4.3 A Study of Street Infrastructure at Two Locations in City A

After site visits to various locations in City A, it was found that at different junctions there were different infrastructures as shown in Fig. 1. There are three different poles installed in a row for three different purposes, namely, streetlight, traffic signal and CCTV pole. The streetlight was installed first at the junction and the traffic light followed later. Another image in Fig. 1 shows the location where traffic light and Street light pole are installed adjacent to each other.

Ideally, this should be optimized so that there can be a cut of expenses on the infrastructure with all the solutions being implemented in the city and utilize it for other projects. Here this can be optimized by keeping both on the same pole and utilizing the existing street infrastructure to its optimum level.

Fig. 1. Image on left shows the junction A where there are three different poles installed for different purpose. The figure on right shows Junction B where there are two different poles installed for different purpose.

4.4 Design Principles for ICT Street Infrastructure

Literature study indicated that there were design guidelines for streets in various cities (Pune, New York, Colombia & Chicago), but there was no clarity about guidelines for ICT infrastructure coming up in the city as a part of smart city mission projects. This results in street infrastructure being placed haphazardly throughout the smart city. So, how should this infrastructure be placed? Where should it be placed on the street? These were questions that needed to be answered.

A detailed study was conducted, and data was collected from various locations in City A. This data included placement of street infrastructure, type of street infrastructure, total count of devices installed and its locations, Operations and management plan for this infrastructure, stakeholders etc. Also based on the data available a detailed study was done for the cost and the bill of material for all locations.

Various stakeholders involved in the street infrastructure were identified. Group discussions were held with members of Special Purpose Vehicle (SPV) of City A, Consultants and System integrators of various ICT projects. As part of stakeholder consultation, it was derived that the design principles for ICT street infrastructure should have a Façade, be Scalable, Safe, Cost-Effective, Sustainable, and Resilient as shown in Fig. 2.

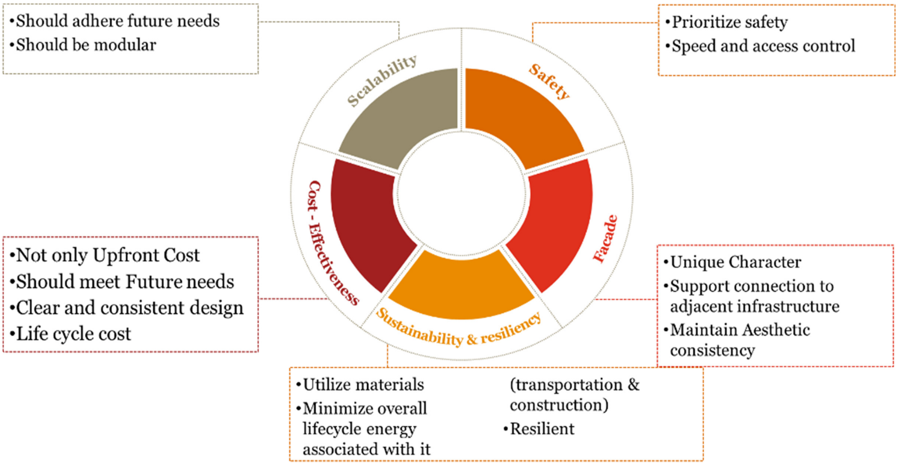

Fig. 2. Design principles for street infrastructure

5 Implementation Phases of ICT Street Infrastructure

All ICT street infrastructures to be placed, go through three phases, namely, Pre-implementation phase, Implementation phase & Post-implementation phase.

5.1 Pre-implementation Phase

The pre-implementation phase includes the design and planning of the street infrastructure for its entire life cycle. The design component includes the design of street infrastructure, which can adhere to the requirement for the present, and the future. The planning component includes the deployment of street infrastructure taking into consideration the location, feasibility and future scalability.

In the existing scenario, there are multiple vendors for multiple infrastructures placed on the streets. Multiple infrastructure increases the complexity of the operation and maintenance of the field devices. As different vendors lay different infrastructure for different IoT components, there are complications in project operations.

For the projects in smart city mission, there is a need to have smart components/sensors/devices on the street which can help to collate data for increasing efficiency and customer satisfaction for the services. Considering the need for infrastructure a design needs to be prepared for the infrastructure and its implementation in such a way that that multiple infrastructure at the same locations can be avoided.

In the proposed optimized street infrastructure, there can be a common shared street infrastructure solution and a single vendor for the street infrastructure. The vendor would do the implementation of civil infrastructure for the smart city. This would help have common, unique, durable and aesthetic infrastructure in streets of the city. This would allow new ICT Infrastructure coming up in the future installed on the common infrastructure available. This makes the scope of both vendors clear for operation and maintenance of the field devices or infrastructure.

5.2 Implementation Phase

Implementation of street infrastructure involves three areas, namely, Civil Infrastructure, Supporting Infrastructure like Electricity box, Junction Box, network connectivity, etc. and the Underground Infrastructure.

Civil infrastructure includes poles/gantry that supports the IT/IoT devices on the street. This infrastructure houses all IoT devices on the street. The existing scenario was understood by the site visits and mapping all civil infrastructure at all locations. The observations at these locations showed that the civil infrastructure for all IoT components was different and this infrastructure was laid adjacent to each other. Duplication of civil infrastructure at all locations increases the CAPEX cost for the project as well as the operation and maintenance costs. It was clear that, to optimize the civil infrastructure a single modular structure where all the current IoT devices can be connected and the devices or sensors that would come in future also can be housed on this structure. A Modular Pole should be so compact that it can stand on the space available at divider on roads. Also, this pole should mount the existing streetlight. Along with streetlight there should be a space available at different heights say 3.5 mts, 4 mts, 4.5 mts & 5 mts to mount devices and sensors coming to that location. So, no additional cost is levied for the civil infrastructure. This makes work easier for all agencies working at the same locations. It also increases the efficiency of the civil infrastructure that is placed in the city as a part of smart city mission projects. Figure 3 shows the sample modular pole installed on the divider as part of the pilot study. It also shows the current layout and the layout after placement of modular poles on road junctions/interactions.

The supporting infrastructure includes electricity box, junction box, network box, etc., this houses all supporting infrastructure for the IoT devices to function; a UPS, switch for OFC, power supply point, network for communication, etc. In the existing scenario, this infrastructure is located at the corner of the junctions. It is then connected to the civil infrastructure laid in the centre of the street by underground connectivity. As the civil infrastructure for all IoT devices is different, so the supporting infrastructure is also different. Thus, multiple junction boxes & electrical boxes can be observed. There is a need to optimize these also. It was possible to integrate the junction box and electrical box to the modular pole, thereby saving space and making it easier for electrical and networking work. So, the junction box and electrical box are integrated into one common box in the modular pole. Also, the IoT was installed on the modular pole. The Modular pole which was installed is seen in Fig. 4.

Underground infrastructure includes electrical line, network line, earthing, etc. that are laid under the ground for the working of the IoT devices. In the existing scenario, it was observed that, the junction box/electrical box are in the corner of the junctions and civil infrastructure is at the centre of the road, thus all their electrical lines and network lines are laid underground. As the IOT components are different, their Junction boxes

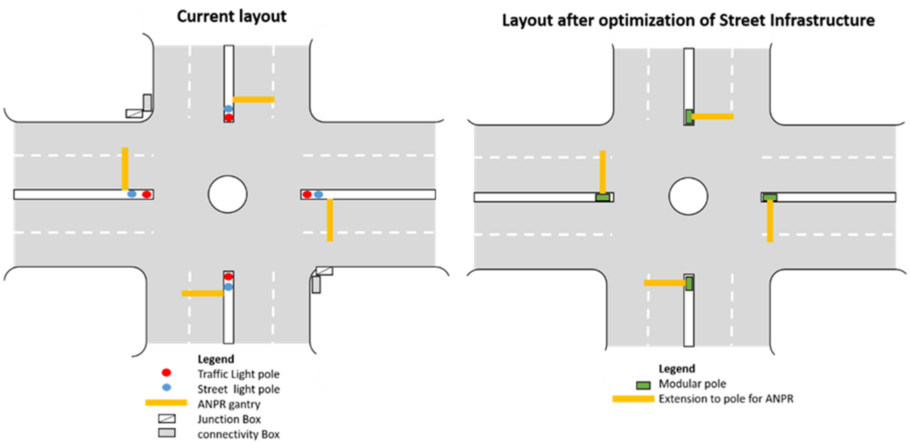

Fig. 3. Placement of modular poles on road junctions/interactions

Fig. 4. Modular infrastructure installed in the city

and electrical boxes are also different. This causes duplicity of lines under the ground. Earthing for each is also different. This results in damage of the road during any maintenance activity and increases the costs of maintenance. The maintenance of different devices at different timings means frequent damage to the road. In order to stop this, a simple procedure can be developed in the city.

All the modular poles need to be connected with each other. A common duct for electrical and network lines is to be laid as a part of connectivity for the poles. The current layout and the optimized layout of common underground infrastructure on road junctions/interactions can be observed in Fig. 5.

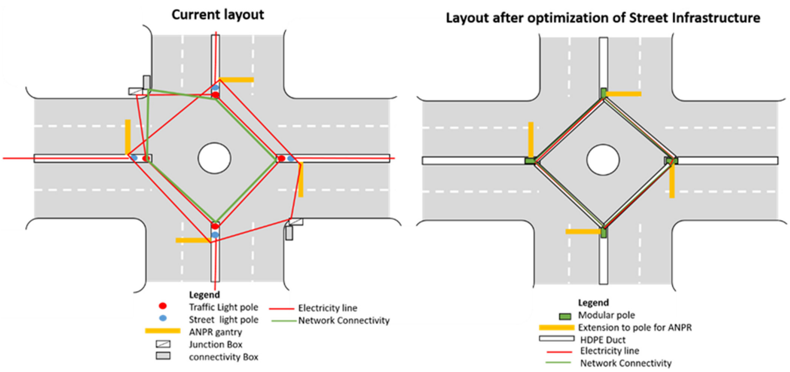

Fig. 5. Placement of common underground infrastructure on road junctions/interactions

Maintenance would involve only a simple trenching to open the duct, thus minimizing the damage to the road. This activity need not be repeated for all devices as they all are connected to the same line at one location. This would remove the duplicity in work, decreasing the operation and maintenance activity, and change the CAPEX and OPEX costs.

5.3 Post-implementation Phase

The post-implementation phase includes operations and maintenance of the street infrastructure installed. The operations and maintenance depend on how the infrastructure was procured and installed, and the type of contract agreed with the vendor and the owner. In some cases, if only the infrastructure is procured and there is no operations and maintenance contract agreed at time of contract, then the municipal corporation itself manages the street infrastructure or it can have new infrastructure maintenance contract after go-live of the infrastructure. In some cases, if the operation and maintenance contract is agreed for a certain period at the time of procurement of the infrastructure then vendor itself operates and maintains the infrastructure for that time period. Post completion of operations and maintenance contract can be renewed or transferred to another party or Municipal Corporation can itself manage the infrastructure.

Operations and maintenance is the most critical period of the street infrastructure, as in that period it facilitates the service operations and it is the period when the municipal corporation can get the payback from the street infrastructure procured. This payback can be monetary or can be citizen service facilitation and satisfaction. This operations and maintenance decide how efficiently the street infrastructure can be used.

In the existing scenario, the street infrastructure procured as a part of a smart city mission is to be operated and maintained by the installing agency for certain years from the go-live of it. But the installation is haphazard on street, and the installing agency knows the installation details and its technical and functional diagrams. The street infrastructure for all different devices/service is different and so any location there is large complexity in the civil, supporting and underground infrastructure and O&M becomes more difficult with time.

In the proposed scenario there is identical street infrastructure at all locations, so there is no location related complexity and there is a single infrastructure at each location that needs maintenance. So, having this identical infrastructure at all locations reduces the complexity and it is also easier for new agency to maintain the street infrastructure when there is a change in operations and maintenance contract.

6 Cost Analysis

The analysis was done for the cost incurred at each location in City A and the cost that can be saved if the street infrastructure at that location is optimized. The cost analysis was done based on the commercial information available of the current system integrator and the quote that came up for new optimized street infrastructure. Based on the site visits the draft BoQ (Bill of Quantity) was filled with the quantities at each location. Then it was analyzed that if all quantities are changed as per the proposed solution of optimization, there can be a calculated percentage difference that can be achieved. Figure 6 shows the analysis done for the field infrastructure utilized in City A with the infrastructure that would be saved if field infrastructure is optimized. Based on this analysis it was observed that there can be a further decrease of 15%–20% in quantity if field infrastructure was optimized.

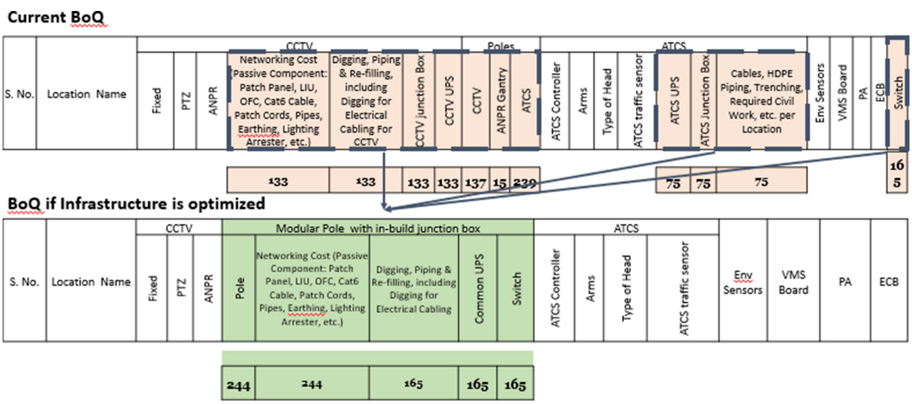

Fig. 6. Analysis on bill of quantity

Based on this BOQ calculation as shown in Fig. 6, cost analysis was done for 10 junctions in the city A. This can be seen in Fig. 7. This helped understand the cost differences arising due to the installation of modular infrastructure at junctions in the city.

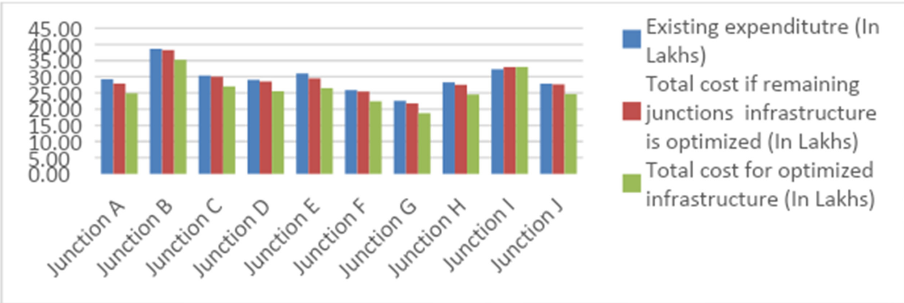

Fig. 7. Cost analysis for junctions in City A

7 Conclusion

Building resilience comes with taking the investment designs wisely and prioritize the efficiency and utilization of the resource allocated. Higher the standardization of the infrastructure and the processes, higher is the resilience of the city. There is a need to understand the urban project and its process of operation and maintenance in the city to contribute to the resilience of the city.

With the change in street infrastructure, there are certain direct benefits that ULB (Urban Local Body) can have and there are some benefits that can be observed with time.

- Sharing of the resources for different ICT systems.
- As all devices are using the same infrastructure and supporting devices, thus, removing the duplicate infrastructure at same location and decreasing the cost incurred for the same.
- Improvement in financials by decrease in the lifecycle cost of asset (by decreasing upfront cost and operations and management cost for the asset installed).
- Providing identical infrastructure throughout the city results in the unique character of infrastructure in the city and helps to maintain the aesthetic consistency.
- Building city resilience to withstand the changes and adopt future technologies.
- Increasing the sustainability by decreasing the street infrastructure and increasing the efficiency of the infrastructure procured.

The aim of this research was to study the current ICT infrastructure in smart cities and the ways available to optimize the infrastructure. The simplest way identified was to have modular poles, that can house the current and upcoming IoT's, also there can be a different research itself to develop a single device which can carry out work of multiple IoT's as it was done in developing Array of Things in Chicago.

Based on the pilot study at a junction in City A, it was found that having a modular pole helped to reduce the components of street infrastructure in the city. It would help to reduce the cost of installation for the additional IoT that will be coming at the junction. Also, the aesthetics of the junction looked unique and similar on all roads' connection at the junction. Over a period of time, it was observed that, and it can help to reduce the complexity of operations and cost of maintenance.

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