KEY PERFORMANCE INDICATORS AND BUILDING INFORMATION MODELING FOR SUSTAINABLE SMART CITY PROJECT IN WESTERN INDIA

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Abstract— Key Performance Indicators (KPI) and Building Information Modeling (BIM) plays a very crucial role in development of a sustainable smart city project. Primarily based on the ideology of the fourth industrial revolution a smart city project should have smart governance, smart health care, smart building, smart transportation, smart mobility, smart energy, smart technology and smart citizen. Considering the Indian scenario of current state of cities in India, it has become very essential to decide the specific parameters which would govern the development of a smart city project. This paper is an attempt to identify the Key Performance Indicators which are significantly responsible for the development of a smart city project in Western India. Reponses of questionnaire survey was analyzed on basis of Likert scale.. They were further critically evaluated with help of Factor Comparison Method (FCM) and Analytical Hierarchy Process (AHP).The project authorities need to incorporate Building Information Modeling (BIM) to make the smart city project more collaborative. To make the project more sustainable, use of flyash in the concrete used, reduced usage of cement and steel, use of alternate fuels like biodiesel is recommended.

Index Terms— Smart City, Key Performance Indicators (KPI), Building Information Modeling (BIM), Factor Comparison Method (FCM), Analytical Hierarchical Process (AHP).

I. INTRODUCTION

The strategic components of Area based development in the Smart Cities Mission are city improvement (retrofitting), city renewal (redevelopment) and city extension (greenfield development) plus a Pan-city initiative in which Smart Solutions are applied covering larger parts of the city. India is urbanizing at an unprecedented rate, so much that estimates suggest near 600 million of Indians will be living in cities by 2030, up from 290 million as reported in the 2001 census. The cities need to be equipped with smart infrastructure to provide suitable jobs to the urban population. This paper is an attempt to study and identify the Key Performance Indicators (KPI) that governs the development of a sustainable smart city project in Western India and also to apply Building Information Modeling (BIM) to make the project more collaborative. With about 30 village dwellers moving every minute from villages to become city dwellers, not many villages will be left India at

the end of this century. Govt. of India has allocated 48000 crore of rupees for initiative to 100 smart cities in country & 50,000 crore for urban infrastructure upgrade of 500 small cities under Atal Mission for Rejuvenation and Urban Transformation (AMRUT YOJNA). Smart Cities is defined as "an emerging conceptual view of a city that promotes the use of Information and Communication Technologies (ICTs) to engage with citizens to develop social capital and intellectual capital, to make better use of hard infrastructure (physical capital), reduce usage of environmental capital and support smart growth (sustainable economic development).

II. LITERATURE REVIEW

[1] has suggested directions and agendas for smart city research and outlines realistic implications of the same. The factors which primarily govern the development of smart cities should be not only related to Information and Communication Technology (ICT), but also other factors which are not directly related with ICT. [2] carried out some work for developing a collaborative model for the smart city development. This collaborative model tries to integrate all the different smart infrastructure facilities required for catering the needs and requirements of urban professionals. These needs were ICT and non ICT based. The critical factors need to be identified from the ICT and non ICT based parameters and evaluated properly by applying proper Multi Criteria Decision Making (MCDM) techniques. [3] have developed a framework on smart city innovation, placing value on an equal importance of technology, organization, policy and context dimensions. [4] has done Qualitative content analysis is used to conduct an in-depth analysis of policy framework of all the development plans in the sample. [5] has discussed about smart cities - concepts, operational definitions, dimensions, technologies that are driving and finally four Indian smart cities. Some people prefer a broader definition: Smart cities use

Information and Communication Technologies (ICT) to be more intelligent and efficient in the use of resources, resulting in cost and energy savings, improved service delivery and quality of life, and reduced environmental footprint - all supporting innovation and the low carbon economy.

[6] stated that BIM is an intelligent model based process that provides insight for creating and managing building and infrastructure projects with faster speed, economy and quality. BIM helps in predicting building performance and also helps in reducing construction wastes. It can also reduce the adverse impact of construction and help to integrate analysis, simulation and visualization into workflow primarily to make informed decisions throughout the project life cycle. [7] made an attempt to use BIM for enhanced collaboration and coordination in real estate projects. The project risk management model developed by [8] for the underground corridor metro rail project would provide a methodology to identify the CSF of the Smart City project under study.

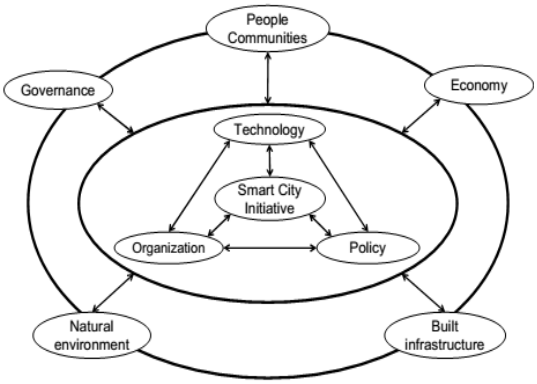


Fig. 1 Smart cities initiative framework [1]

III. CASE STUDY

Gandhinagar has been selected as one of the hundred Indian cities to be developed as a smart city under flagship Smart Cities Mission. Thirty sectors, into which the city has been divided, stretch around the central Government complex. Each sector has its own shopping and community center, primary school, health center, government and private housing. There is a provision for of parks, extensive planting and a recreational area along the river giving the city a green garden-city atmosphere. Factors declared by Govt. of India for smart city developments are also taken into consideration. They are broadly classified into following categories:

- Public and Social Service
- Environment
- E-Governance
- ICT
- Mobility
- Infrastructure
- Tourism

Public and Social Service
- E-Admin
- Open Data Network
- Healthcare
- Virtual Citizen office
- Education
- Skill Development
- Sr. Citizen Centre
- Culture & Recreation Environment
- Smart Domestic Waste Collection
- Metered Water
- Solid Waste Management
- Smart Grid
- Carbon Emission
- Green Field Development

E-Governance
- Single Window operation
- Ease of doing Business
- Policy & Procedures
- E-Administration
- Online Tendering
- Zero Corruption

Mobility
- Public Transport
- Auto Rickshaw's
- Promoting Bicycle
- Smart Parking
- Smart Traffic Lights
- Walkways
- Traffic App

ICT
- Open Data Network
- City Cloud
- Smart Innovation
- Wireless City
- Mobile ID

Infrastructure
- Smart Transportation
- High Speed Wi-Fi
- Telecommunication Network
- SEZ, SIR
- LIG, MIG Housing
- Industrial Corridor
- Public Parks and Recreation Centre

IV. CASE ANALYSIS

All the available parameters are critically evaluated for all the parameters which are described below. Parameters are compared with each other to find out relative weightage of each parameter, for this purpose

we have used the point scale system, considering major difference, minor difference, medium difference, and no difference a comparative rating scale is formulated as "Major difference =3"; "Medium difference =2"; "Minor difference = 1" and "No difference = 0".The weightage each parameter is based on individual experience and decision may vary from individual to individual. Relative weightage of each parameter is derived separately for all the different parameters. Depending on the relative weightages they are given ranks, once weightage of each parameter is decided, the top 3 rank parameters from each of the matrix will be selected, after selecting top 3 parameters from all the matrix, new interdependent matrix will be developed.

TABLE 1
LIST OF PARAMETERS FOR SMART CITY

Public & Social Service	A
Environment	B
Mobility	C
E- Governance	D
Information and communication Technology (ICT)	E
Infrastructure	F
Smart Tourism	G
Miscellaneous	H

TABLE 2
FACTORED MATRIX FOR PARAMETERS FOR SMART CITY

	B	C	D	E	F	G	H	SCORE	RANK
A	A2	C2	A2	E1	F3	A1	A2	7	3
	B	C2	B2	E1	F2	B2	B1	5	5
		C	C3	C1	C1	C1	C2	11	2
			D	E2	F1	D2	D1	3	6
				E	F1	E2	E1	6	4
					F	F2	F3	12	1
						G	G1	1	8
							H	1	7

AHP Analysis was used for determining the Key Performance Indicators affecting feasibility of smart infrastructure and cities. AHP analysis was used for all the major parameters decided further using various models which are as follows:

- Public and Social service
- Environment
- E- Governance
- ICT
- Mobility
- Infrastructure
- Smart Tourism
- Miscellaneous Factors

TABLE 3
AHP ANALYSIS FOR PUBLIC AND SOCIAL SERVICE PARAMETERS FOR SMART CITY

No	Parameters	Weights	Rank
1	E- Admin	30.6%	1
2	Open Data Network	12.4%	3
3	Healthcare	4.5%	5
4	Education & Skills	12.4%	3
5	Sr. Citizen Centre	3.4%	7
6	Culture	2.5%	8
7	Recreation	4.5%	6
8	Standard of Living	29.8%	2

TABLE 4
PRINCIPAL VECTOR MATRIX FOR PUBLIC AND SOCIAL SERVICE PARAMETERS FOR SMART CITY

		1	2	3	4	5	6	7	8
Criterion 1	1	0	3	7	3	9	9	7	1
Criterion 2	2	1/3	0	3	1	5	5	3	1/3
Criterion 3	3	1/7	1/3	0	1/3	1	3	1	1/7
Criterion 4	4	1/3	1	3	0	5	5	3	1/3
Criterion 5	5	1/9	1/5	1	1/5	0	1	1	1/7
Criterion 6	6	1/9	1/5	1/3	1/5	1	0	1/3	1/9
Criterion 7	7	1/7	1/3	1	1/3	1	3	0	1/7
Criterion 8	8	1	3	7	3	7	9	7	0

The result of this analysis is that lambda (ƛ) = 8.178; GCI = 0.07, and CR: 1.8%. CR value of less than 10% indicates the data is reliable and model can be taken into consideration for developmental factors of smart city.

TABLE 5
AHP ANALYSIS FOR ENVIRONMENT PARAMETERS FOR SMART CITY

No	Parameter	Weights	Rank
1	Recycling Take up by residents & Businesses	43.7%	1
2	Metered Water	15.8%	3
3	Solid Waste Management	6.8%	5
4	Smart grid	6.4%	6
5	Carbon Emission	8.6%	4
6	Green Field Development	18.6%	2

The result of this analysis is ƛ= 6.151; GCI = 0.09 and CR = 2.4%. CR value of less than 10% indicates the data is reliable and model can be taken into consideration for developmental factors of smart city.

TABLE 6
AHP ANALYSIS FOR MOBILITY PARAMETERS FOR SMART CITY

No	Parameter	Weights	Rank
1	Public Transport	49.8%	1
2	E- Vehicles	8.7%	5
3	Promoting Bicycle	7.9%	6
4	Smart Parking	8.9%	4
5	Smart Traffic Lights	9.2%	2
6	Walkways	9.2%	2
7	Traffic App	6.3%	7

The result this analysis is ƛ = 7.899; GCI = 0.38 and CR: 7.2%. CR value of less than 10% indicates the data is reliable and model can be taken into consideration for developmental factors of smart city.

TABLE 7
AHP ANALYSIS FOR E GOVERNANCE PARAMETERS FOR SMART CITY

No	Parameter	Weights	Rank
1	Single Window Operation	28.1%	1
2	Ease of Doing Business	21.7%	2
3	E-Administration	12.4%	5
4	Policy and Procedures	14.7%	4
5	Online Tendering	5.3%	6
6	Zero Corruption	17.7%	3

After carrying out adequate study for identifying critically evaluated parameters for smart city, the most appropriate method is AHP. This process generates evaluation of the weightage for critical success factors in form of normalised principal vector. AHP generates Consolidated Matrix, Weighted Average Matrix and Eigen value matrix which results in final outcome. Infrastructure, Mobility and Public & Social Service are the three Key Performance Indicators evaluated from the AHP process.

The most important Key Performance Indicator for "Public and social service" are E-admin (rank 1, weightage 30.6%) and "Standard of living" (rank 2, 29.8%). For "Environment" parameters the Key Performance Indicators are Recycling taken up by residence (rank 1, 43.7%) and Green field development (rank 2, 18.6%). For "Mobility" parameter the most important Key Performance Indicators are Public transport (rank 1, 49.8%) and Walkways (rank 2, 9.2%). For E-governance the most vital Key Performance Indicators are Single window operation (rank 1, 28.1%) and Ease of doing business (rank 2, 21.7%). For "ICT" the most critical indicator are Wireless world (rank 1, 32.8) and Mobile ID (rank 2, 29.6). For "Infrastructure" the most critical indicators are Industrial corridor (rank 1, 38.6%) and Smart transportation (rank 2, 155%). For "Smart tourism" the critical indicators are Infrastructure marvels (rank 1, 41.7%) and Heritage development (rank 2, 22.4%). Finally for some "Miscellaneous" factors, the most critical indicators are City app (rank 1, 29%) and Skill development (rank 2, 11.8%).

To make the project sustainable use of low energy consuming materials need to be promoted. Use of more energy consuming materials like cement and steel need to be minimized. Use of flyash need to promoted in all construction activities. All the concrete used for the project need to be designed with flyash. Use of led lights need to be promoted. Use of smart energy meters need to be promoted. Use of alternative fuels like biodiesel need to be promoted. More usage of renewable energy sources like solar and wind energy need to be encouraged. Smart solid waste management system and recycling of plastic wastes are mandatory components for developing a smart city project. Usage of Building Information Modeling (BIM) and cloud computing would increase collaboration and co-ordination between the various activities of the smart city project. Finally Integrated Mass Rapid Transit system (IMRTS) which would integrate the popular modes of MRTS system like metro rail (underground), metro rail (elevated), monorail, Bus Rapid Transit System (BRTS) need to be encouraged for developing the smart city project.

CONCLUSIONS

Analysis from Factor Comparison Method (FCM) has revealed that amongst the Key Performance Indicators (KPI) "Infrastructure" is the most critical indicator that the project authorities need to carefully deal with. This factor has obtained a score of 12 and obtained rank 1. The second indicator is "Mobility" (score 11 and rank 2). Third factor is "public and social service

(score 7, rank 3). Fourth indicator is "Information and Communication Technology (ICT)" (score 6, rank 4) followed by "Environment" (score 5, rank 5), "E-governance" (score 3, rank 6) and "Smart tourism" (score 1, rank 7). Some "Miscellaneous" parameters also has obtained the same rank as that of "Smart tourism". From Analytical Hierarchy Process (AHP) analysis "Public and Social service factors related to smart cities which are critical for its feasibility has E-admin (rank 1, weightage 30.6%) and "Standard of living" (rank 2, 29.8. "Environment" factors related to smart cities which are critical for its feasibility have Recycling taken up by residence (rank 1, 43.7%) and Green field development (rank 2, 18.6%). Also, Metered water, Carbon emission and Solid waste management need to be taken care by the project authorities for proper development of the smart city project."Mobility" factors related to smart cities which are critical for its feasibility are Public transport, Walkways and Smart traffic Lights. "E-Governance" factors related to smart cities which are critical for its feasibility are Single window operation, zero corruption and Ease of doing business. "Information and Communication Technology (ICT)" factors related to smart cities which are critical for its feasibility are Open data network, Wireless world and Smart innovation. "Infrastructure" factors related to smart cities which are critical for its feasibility are Educational facilities, Industrial corridor and Smart transportation. "Smart tourism" factors related to smart cities which are critical for its feasibility are Advertising campaign, Infrastructure marvels and Tourism promotion. Furthermore, "Miscellaneous" factors related to smart cities which are critical for its feasibility are Virtual citizen advice office, Smart citizen and Transparency in business.

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