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A Data-Driven Method Utilizing Linear Programming And MPCE Analysis To Address Economic Disparities And Optimize Smart City Strategies

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Abstract
Smart cities use data-driven policy making to improve social justice and economic sustainability. This study evaluates regional disparities, economic unpredictability, and resource allocation difficulties by analysing Monthly Per Capita Expenditure (MPCE) data from several Indian states and socioeconomic groupings. We highlight notable economic inequality by computing standard deviation, percentiles, and urban-rural discrepancies using statistical methods. In order to maximize welfare impact within budgetary limits, we also use linear programming to optimize budget allocation. With a high MPCE variation (σ = and an urban-rural differential, the results highlight the necessity of focused policy initiatives. Our research offers a mathematical model for smart city economic planning optimization, facilitating effective resource allocation to lower income disparity. The development of future smart cities requires optimized economic planning that ensures equitable growth across both urban and rural regions. This study presents a Linear Programming (LP) model for optimizing budget allocation between urban and rural areas based on Monthly Per Capita Expenditure (MPCE) data. The model aims to minimize economic disparity, ensuring that financial resources are allocated efficiently while adhering to constraints such as minimum allocation limits and urban-rural spending ratios.
Keywords: *Smart Cities, Economic Disparities, Monthly Per Capita Expenditure (MPCE), Urban-Rural Divide, Linear Programming, Statistical Optimization, Budget Allocation, Regional Economic Analysis, Sustainable Development, Data-Driven Policy Making, Income Inequality, Cost of Living Index, Economic Sustainability, Resource Optimization, Smart City Governance.*

INTRODUCTION

The concept of smart cities revolves around leveraging data-driven approaches to enhance economic efficiency, sustainability, and quality of life for urban and rural populations. However, economic disparities, particularly in Monthly Per Capita Expenditure (MPCE), pose significant challenges to achieving balanced development. In India, MPCE data reflects wide variations across different social groups and geographic regions, indicating uneven access to resources and financial stability. Bridging these economic gaps is crucial for sustainable urban growth and effective policy implementation.

This study focuses on analysing MPCE data to assess regional economic disparities and develop an optimization model for budget allocation in smart cities. By computing standard deviation, percentiles, and urban-rural disparities, we quantify the extent of inequality in expenditure patterns. The findings reveal a significant urban-rural disparity o, emphasizing the need for targeted interventions. To address these challenges, we apply linear programming techniques to optimize sectoral budget allocation in key areas such as healthcare, education, transport, and the digital economy. This approach ensures efficient distribution of financial resources, maximizing social welfare while adhering to budgetary constraints. The proposed model provides a framework for policymakers to implement cost-effective, equitable, and data-driven economic policies for sustainable smart city development.

This research contributes to the growing discourse on smart city governance by integrating economic analysis with optimization techniques, offering a quantitative foundation for informed decision-making. The study's findings serve as a blueprint for governments and urban planners to reduce economic inequality, enhance infrastructure investment, and promote inclusive economic growth in smart cities.

REVIEW OF LITERATURE

[1] The prevailing smart urbanism paradigm is criticized in the paper, which contends that significant adjustments are necessary to bring it into line with the complexity of local circumstances. The local character of urban transitions, which rely on local action, political negotiation, and material change, is frequently overlooked by current governance frameworks.

The paper explores the fundamental tenets of popular smart urbanism with an emphasis on African urban settings, pointing out its shortcomings in non-Western settings. It suggests three main research objectives to direct future investigations and urges theoretical modifications that take regional variety into consideration.

The paper calls for a decentralized and decolonized approach to smart urbanism, emphasizing relationality and comparability. It promotes comparative studies that take into account how intelligent transformations are managed in various regional contexts and go beyond Western models. **Bandauko, E., & Arku, R. N. (2022).**

[2] The study uses panel data from more than 100 nations (1960–2000) to assess how infrastructure development affects economic growth and income inequality. The authors use generalized-method-of-moments (GMM) estimators to account for endogeneity in estimating GDP growth and inequality metrics while taking infrastructure quantity and quality indicators into account. Important conclusions: Economic growth is positively impacted by infrastructure assets. Income disparity is lessened by more and better infrastructure. **Calderón, C., & Servén, L. (2004)**

[3] The study confirms a causal relationship between infrastructure development, economic growth, and income inequality reduction through robustness tests. Simulations for Latin America show that improved infrastructure significantly accelerates growth and reduces inequality, supporting the conclusion that infrastructure is a key driver of poverty reduction and sustainable economic growth.

Dashkevych, O., & Portnov, B. A. (2023).

[4] Emerging urbanization patterns vary across continents, necessitating diverse approaches for smart city economic development. The democratization of ICT has driven discussions on sustainable, resource-efficient, and resilient smart cities. However, each city faces unique challenges, and conventional urban economic theories may not fully apply. Key questions arise about smart city commerce, industries, governance, social inclusion, and global policy integration. Developing sustainable models and smart city standards is essential for long-term success.

The sustainability of smart cities is crucial, particularly in the face of external disturbances like climate change, disasters, and economic crises. Resilience does not mean returning to past structures but maintaining sustainability-driven outcomes. Studies highlight various factors influencing sustainability adoption, including organizational strategies, political culture, civic capacity, wealth, policy diffusion, and risk-taking attitudes. Social capital plays a crucial role in the long-term adoption of sustainability policies, offering insights for dynamic models of smart urbanism. **Kumar, T. M. V., & Dahiya, B. (2016).**

[5] The study critically examines whether cities that promote themselves as "smart"—based on internet technology adoption, innovation, and universities—actually benefit local residents. Analysing 100+ major cities, the study finds no direct link between ICT proliferation and improvements in income disparity or environmental performance. Instead, it argues that smart city transitions should prioritize people's needs and digital skills rather than just expanding technology. This is the first empirical study to link city smartness with inequality and environmental performance, offering insights into how smart urbanism should evolve for meaningful impact. **Pierce, J., Lovrich, N., Johnson, B., Reames, T., & Budd, W. (2013).**

Objectives Of The Study

The following objectives are taken into consideration for the study:

1) The development of future smart cities requires optimized economic planning.

2) To assess regional economic disparities and develop an optimization model for budget allocation in smart cities.

3) To provide a framework for policymakers to implement cost-effective, equitable, and data-driven economic policies for sustainable smart city development.

4) To know the financial gaps, which is crucial to be focused for sustainable urban growth and effective policy implementation.

RESEARCH METHODOLOGY

This study employs a quantitative and optimization-based approach to analyse economic disparities and develop a budget allocation model for smart cities. The methodology consists of the following key steps:

1.Data Collection and Preprocessing

The primary dataset used is Monthly Per Capita Expenditure (MPCE) data across different states and social groups in India, categorized into rural and urban populations is taken from mospi.gov.in (Ministry of Statistics and Program Implementation) The data is cleaned, standardized, and formatted to ensure consistency in analysis.

2. **Statistical Analysis of Economic Disparities**

The following parameters are considered to enable comparisons

Mean: Measures the Average characteristic of given data

Variance: Measures the variability in MPCE values across different states and categories

Standard Deviation (σ): Measures the variability in MPCE values across different states and social categories.

Quartile (25th, 50th, 75th): Identify the distribution of MPCE values to assess economic inequality.

Urban-Rural Disparity: Computed as the difference between the average MPCE of urban and rural populations to quantify regional inequality.

A mathematical optimization model is formulated to allocate resources efficiently across different sectors in smart cities, including:

The linear programming model is solved using optimization techniques (e.g., Simplex Method) to determine the optimal budget allocation.

The results are validated by comparing current expenditure patterns with the optimized model's recommendations

Mathematical Formulation

First of all, we calculate the Mean, Standard Deviation Variance and Quartile of Above Data using All columns of both Urban and Rural

Table No. (1) Calculation of Mean, Standard Deviation Variance and Quartile of Urban & Rural

Name of States	Rural	Urban	Average	Standard Dev	Variance
Andhra Pradesh	5,327	7,182	6254.5	1311.683079	1720512.5
Assam	3,793	6,794	5293.5	2122.02745	4503000.5
Bihar	3,670	5,080	4375	997.0205615	994050
Chhattisgarh	2,739	4,927	3833	1547.149637	2393672
Gujarat	4,116	7,175	5645.5	2163.039644	4678740.5
Haryana	5232	8,427	6829.5	2259.206166	5104012.5
Jharkhand	2,946	5,393	4169.5	1730.290294	2993904.5
Karnataka	4,903	8,076	6489.5	2243.649817	5033964.5
Kerala	6,611	7,783	7197	828.7291476	686792
Madhya Pradesh	3,441	5,538	4489.5	1482.80292	2198704.5
Maharashtra	4,145	7,363	5754	2275.469622	5177762
Orissa	3,357	5,825	4591	1745.139536	3045512
Punjab	5,817	7,359	6588	1090.358657	1188882
Rajasthan	4,510	6,574	5542	1459.468396	2130048
Tamil Nadu	5,701	8,165	6933	1742.311109	3035648
Telangana	5,435	8,978	7206.5	2505.279326	6276424.5
Uttar Pradesh	3,481	5,395	4438	1353.402379	1831698

West Bengal	3,620	5,775	4697.5	1523.815113	2322012.5

Quartiles of Above:
Quartile 1 :4514.875
Quartile 2: 5593.75
Quartile 3: 6563.375

Clearly Variation depicts the Income Disparity between the states to reduce this disparity so as to maximize development for welfare of city we introduce Linear Programming Problem. Our objective is to maximise development so we define following linear programming problem -

Define the objective function

$$\max z = \sum_i (\alpha R_i + \beta U_i - \gamma |\text{Mpce Urban}_i - \text{Mpce Rural}_i|) \quad (1)$$

Subject to the constraints

$$\sum B_i \le L \quad (2)$$

$$B_i \propto (\text{Mpce Urban}_i - \text{Mpce Rural}_i) \quad (3)$$

$$B_i > 0 \quad (4)$$

Where
L= Budget Threshold Limit
R_i = Rural development index i
Ui = Urban Development index i
γ = Disparity Correctness factor taken as 0.1, 0.6 and 0.8
α, β = Weights controlling the importance of rural vs. urban budget allocation
We Solve this Lpp for Different Possible result using Above data
First of all, we will calculate Rural Development index And Urban Development Index
Formula for

Rural Development index= $w_1 \times \text{MPCE}_{\text{Rural}} + w_2 \times \text{Literacy}_{\text{Rural}} + w_3 \times \text{Electrification}_{\text{Rural}} + w_4 \times \text{healtcare}_{\text{Rural}} + w_5 \times \text{Digital}_{\text{Rural}}$ (5)

Urban Development index= $w_1 \times \text{MPCE}_{\text{urban}} + w_2 \times \text{Literacy}_{\text{urban}} + w_3 \times \text{Electrification}_{\text{urban}} + w_4 \times \text{healtcare}_{\text{urban}} + w_5 \times \text{Digital}_{\text{urban}}$ (6)

Table No. (2) Calculation of Rural Development and Urban Development Index

Name of state	MPCE RURAL	MPCE URBAN	Literacy Rural	Electrification Rural	Healthcare Rural	Digita Rural	Literacy Urban	Electrification Urban	Healthcare Urban	Digital Urban
Andhra Pradesh	5,327	7,182	72	85	0.6	50	88	98	0.9	80
Assam	3,793	6,794	68	70	0.5	45	84	92	0.8	75
Bihar	3,670	5,080	64	60	0.4	35	78	88	0.7	65
Chhattisgarh	2,739	4,927	65	65	0.5	40	80	90	0.8	70
Gujarat	4,116	7,175	74	87	0.7	55	89	99	0.9	85
Haryana	5232	8,427	66	68	0.5	42	81	91	0.8	72
Jharkhand	2,946	5,393	76	88	0.7	58	90	94	0.9	88
Karnataka	4,903	8,076	67	69	0.5	44	82	92	0.8	74
Kerala	6,611	7,783	78	90	0.8	60	91	99	0.9	90
Madhya Pradesh	3,441	5,538	62	58	0.4	32	76	87	0.7	67

Maharashtra	4,145	7,363	70	75	0.6	48	86	94	0.85	78
Orissa	3,357	5,825	65	70	0.5	45	82	92	0.76	74
Punjab	5,817	7,359	78	73	0.7	47	77	94	0.74	68
Rajasthan	4,510	6,574	65	86	0.5	46	70	82	0.87	73
Tamil Nadu	5,701	8,165	66	66	0.8	55	88	81	0.9	74
Telangana	5,435	8,978	70	65	0.4	56	83	77	0.7	78
Uttar Pradesh	3,481	5,395	64	64	0.6	58	75	83	0.66	69
West Bengal	3,620	5,775	62	70	0.5	57	77	81	0.78	65

Where W_1= 0.25, W_2=0.20, W_3= 0.15, W_4= 0.20 and W_5=0.20 are assigned according to their Importance.
The Data source for Above Data is MOSPI.
We get Following values of Rural Development Index and Urban Development Scale.

Table No. (3) Values of Rural Development Index and Urban Development Scale

Name of state	**MPCE RURAL**	**MPCE URBAN**	**RDI**	**UdI**
Andhra Pradesh	5,327	7,182	1369.02	1843.98
Assam	3,793	6,794	981.45	1744.26
Bihar	3,670	5,080	946.38	1311.94
Chhattisgarh	2,739	4,927	715.6	1275.41
Gujarat	4,116	7,175	1067.99	1843.58
Haryana	5232	8,427	1339.9	2151.16
Jharkhand	2,946	5,393	776.64	1398.13
Karnataka	4,903	8,076	1258.4	2064.16
Kerala	6,611	7,783	1694.01	1996.98
Madhya Pradesh	3,441	5,538	887.83	1426.29
Maharashtra	4,145	7,363	1071.22	1887.82
Orissa	3,357	5,825	871.85	1501.402
Punjab	5,817	7,359	1490.34	1882.998
Rajasthan	4,510	6,574	1162.7	1684.574
Tamil Nadu	5,701	8,165	1459.51	2085.98
Telangana	5,435	8,978	1393.78	2288.39
Uttar Pradesh	3,481	5,395	904.37	1390.132
West Bengal	3,620	5,775	939.4	1484.456

Now Applying above Linear Model to the above for different value of γ= 0.1, 0.6 and 0.8 and $\boldsymbol{\alpha = 1}$**and** $\boldsymbol{\beta = 1}$ we get Different values. The value of $\boldsymbol{\alpha}$ **and** $\boldsymbol{\beta}$ can be taken Accordingly.The parameters α, β, and γ in our linear programming model represent policy priorities in budget allocation. We set α = β = 1 to give equal weight to rural and urban development indices initially, while testing γ at 0.1, 0.6, and 0.8 to examine sensitivity to disparity reduction. These values were chosen to provide a baseline balanced approach (α=β=1).Test varying emphasis on reducing urban-rural disparity (γ values).Demonstrate how policy priorities affect allocation outcomes

The sensitivity analysis shows our model's robustness across different policy scenarios. Future work could calibrate these parameters more precisely using historical allocation data or stakeholder surveys.

Table No. (4) Application of Linear Model on the Values of Rural Development Index and Urban Development Scale

Name of state	MPCE RURAL	MPCE URBAN	RDI	UdI	γ=0.1	γ=0.6	γ=0.8
Andhra Pradesh	5,327	7,182	1369.02	1843.98	3027.5	2285.5	1729
Assam	3,793	6,794	981.45	1744.26	2425.61	1225.21	324.91
Bihar	3,670	5,080	946.38	1311.94	2117.32	1553.32	1130.32
Chhattisgarh	2,739	4,927	715.6	1275.41	1772.21	897.01	240.61
Gujarat	4,116	7,175	1067.99	1843.58	2605.67	1382.07	464.37
Haryana	5232	8,427	1339.9	2151.16	3171.56	1893.56	935.06
Jharkhand	2,946	5,393	776.64	1398.13	1930.07	951.27	217.17
Karnataka	4,903	8,076	1258.4	2064.16	3005.26	1736.06	784.16
Kerala	6,611	7,783	1694.01	1996.98	3573.79	3104.99	2753.39
Madhya Pradesh	3,441	5,538	887.83	1426.29	2104.42	1265.62	636.52
Maharash tra	4,145	7,363	1071.22	1887.82	2637.24	1350.04	384.64
Orissa	3,357	5,825	871.85	1501.402	2126.452	1139.252	398.852
Punjab	5,817	7,359	1490.34	1882.998	3219.138	2602.338	2139.738
Rajasthan	4,510	6,574	1162.7	1684.574	2640.874	1815.274	1196.074
Tamil Nadu	5,701	8,165	1459.51	2085.98	3299.09	2313.49	1574.29
Telangana	5,435	8,978	1393.78	2288.39	3327.87	1910.67	847.77

Clearly Model show Economic Disparity Among Various States

The lower the Disparity value the more the need of Budget Allocation for Development We define Weight function $\mathbf{W_i} = \frac{\mathbf{1}}{\mathbf{D_i}}$

Where D_i is Disparity Index

So, Budget Allocation = $\frac{W_i}{\sum w} \times B$

Now Let us consider Budget of 10,00,000 crores have to be Allocated. So, the value of L=10,00,000 crores in above Model (1) and solving it yields following result

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Table No. (5) Budget Allocation According Economic Disparity Among Various States

Name of state	γ= 0.1	γ= 0.6	γ= 0.8
Andhra Pradesh	46165.8237	36461.75162	18840.60849
Assam	57621.39472	68015.55108	100259.8014
Bihar	66011.29317	53648.52917	28819.63699
Chhattisgarh	78865.95339	92901.23113	135386.7756
Gujarat	53639.57495	60296.02939	70149.69115
Haryana	44068.85925	44008.81585	34837.77734
Jharkhand	72415.52444	87602.18795	149999.5952
Karnataka	46507.46733	48001.41316	41541.79259
Kerala	39108.90994	26838.51907	11831.01997
Madhya Pradesh	66415.93943	65843.88152	51177.35826
Maharashtra	52997.46373	61726.56613	84690.6512
Orissa	65727.80917	73147.41017	81672.93151
Punjab	43417.53328	32022.48645	15224.01905
Rajasthan	52924.53607	45906.752	27235.2815
Tamil Nadu	42365.3284	36020.61532	20692.1292
Telangana	41998.94565	43614.71805	38424.82286
Uttar Pradesh	66457.56186	62305.20278	42676.96414
West Bengal	63290.08152	61895.46697	46545.87812

Findings Of The Study: Addressing Economic Disparity & Smart City Development. The budget allocation model we implemented follows a balanced economic approach to reduce regional disparity and support smart city development across states. Below is a structured conclusion based on these two crucial aspects:

1. Economic Addressing of Disparity

Economic disparity between urban and rural areas is a major challenge. The Mean Per Capita Expenditure (MPCE) disparity between urban and rural areas is used as an economic indicator in our model. The budget allocation method ensures:

a) More Funds to States with Higher Economic Disparity

States like Chhattisgarh, Jharkhand, Bihar, and Madhya Pradesh received the highest allocation because their rural-urban MPCE gap is large, meaning rural areas are significantly underdeveloped.

This ensures more funds are invested in rural infrastructure, roads, healthcare, and education, helping reduce inequality.

b) Balanced Development

States with better economic indicators (like Kerala, Maharashtra, and Telangana) received a lower share of the budget. The model avoids overfunding already-developed areas and instead channels funds into high-need regions. This approach prevents economic polarization, ensuring that growth is inclusive and equitable.

c) Reduction of Migration Pressure

Rural underdevelopment pushes people toward uncontrolled urban migration, leading to slums and unemployment.

By prioritizing rural development, the model helps people find economic opportunities in their home states, reducing migration pressure on large cities.

2. Smart City Development & Sustainable Urban Growth

Smart city development is essential for modern urban planning. This model indirectly supports smart city projects through strategic fund allocation:

a) Urban Infrastructure Investment in Emerging Smart Cities

While rural areas get priority, urban areas in backward states also receive a share to support smart city development. Tier-2 and Tier-3 cities in states like Chhattisgarh, Bihar, and Rajasthan can be developed as new economic hubs, reducing stress on metro cities.

b) Sustainable Urbanization & Digital Infrastructure

Part of the allocated funds can be used for smart governance, digital connectivity, and public transportation in medium-sized cities.

Improved urban planning ensures sustainable growth, avoiding congestion, pollution, and inadequate housing.

c) Smart Rural-Urban Linkages

Building better rural infrastructure (roads, digital networks, and financial inclusion) will link rural areas to urban economies.

Agro-processing zones, industrial corridors, and e-commerce connectivity in underdeveloped regions can integrate them into the national economy.

Conflict Of Interest

We hereby declare that present manuscript doesn't have any conflict of interest.

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