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RESEARCH PAPER

Comparative Analysis of SDG-Aligned Performance Indicators across Major Cities of Punjab

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ABSTRACT

The study aims to evaluate socio-economic, cultural, environmental, and infrastructural disparities across six major cities of Punjab—Lahore, Rawalpindi, Faisalabad, Multan, Sargodha, and Bahawalpur—through the lens of SDG-aligned performance indicators to inform sustainable development policies. Punjab's cities exhibit significant variations in development trajectories, with urban centers like Lahore experiencing rapid economic growth and resource consumption, while rural cities like Sargodha and Bahawalpur lag behind in infrastructure and economic opportunities. Data was collected from the Bureau of Statistics, open datasets, the Compendium of Environmental Statistics, and utility centers of the respective cities. Descriptive and exploratory data analysis techniques were applied to compare city-level performance across sustainability dimensions. Lahore's rapid urbanization leads to high GDP and resource consumption but causes significant environmental degradation. Faisalabad, Rawalpindi, and Multan struggle to balance industrial growth with environmental sustainability, while rural cities face challenges in socio-economic development. Tailored policy measures, including promoting green industrial practices, equitable resource allocation, and infrastructure development, are essential to foster balanced and inclusive growth across Punjab's cities.

KEYWORDS Cities' Sustainability, Descriptive Analysis, Exploratory Analysis, SDG-Aligned Performance Indicators

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Introduction

Sustainable Development Goals (SDGs), established by the United Nations, provide a framework for fostering global sustainability, with particular emphasis on Sustainable Cities and Communities (SDG 11) to enhance urban environments and citizen's quality of life (Sorooshian, 2024; Siddiqui, 2023; Biglari, 2022). Cities, as centers of economic, social, and environmental change, are vital to achieving the SDGs (Yu et al., 2025; Jia et al., 2024; Yamasaki & Yamada, 2022). In Punjab, Pakistan's largest and most dynamic cities, monitoring SDG-aligned performance is essential for identifying gaps and advancing sustainability (Salman & Wang, 2024; Rehman et al., 2021). Punjab's major cities significantly contribute to GDP and address key SDG targets related to poverty, health, and environmental sustainability (Raza et al., 2024; Gul et al., 2023). However, disparities in resource allocation, infrastructure, and governance create uneven progress, with cities like Lahore and Faisalabad leading in industrial and economic development, while Multan and Sargodha face challenges in infrastructure and environmental management (Ahmed et al., 2024; Zhang et al., 2024). These variations underscore the need for city-specific performance evaluations to tailor sustainable development strategies.

Research shows that cities adopting localized SDG frameworks are better positioned to balance economic growth with social and environmental goals (Islam et al., 2023; Zhou et al., 2022). This is especially relevant for Punjab, where rapid urbanization exacerbates housing shortages, traffic congestion, and climate vulnerability (World Bank, 2022). However, research on Pakistani cities remains limited, with a lack of city-specific analyses on sustainability performance and intra-regional variations (Islam et al., 2023; Raza et al., 2022). While Lahore and Faisalabad have received considerable attention in national development policies, cities like Multan and Bahawalpur, despite their economic importance, remain underrepresented in empirical studies (Ahmed et al., 2023; World Bank, 2022). This imbalance in research leads to skewed resource allocation and limits understanding of unique city challenges.

Existing literature often relies on aggregate provincial or national indicators, masking local disparities and hindering targeted interventions (Kim et al., 2024; Zhou et al., 2022). By focusing on SDG-aligned indicators for six major cities of Punjab, this study aims to address these gaps, offering a comparative performance analysis that highlights regional sustainability challenges. It emphasizes the need for localized SDG monitoring to inform policy decisions and promote inclusive, sustainable development. The findings are expected to guide policymakers in addressing city-specific sustainability challenges in Punjab.

Literature Review

A growing body of literature emphasizes the significance of localizing the SDGs to address regional disparities and foster inclusive development. For example, (Ma, et al., 2025; Huang et al., 2023; Zhou et al. 2022; Liang & Gong, 2020) highlight the importance of city-level analyses in understanding the diverse trajectories of sustainability in developing countries. Their findings underscore that localized monitoring frameworks enable cities to better align with SDG targets, addressing challenges specific to their socio-economic and environmental contexts. Similarly, Ahmed et al. (2023) argue that city-level data provide policymakers with actionable insights to prioritize investments and interventions for sustainable development.

There is an ever-growing body of research on city-specific SDG-aligned indicators, particularly in Chinese cities. Li et al. (2024) emphasize the need for localizing SDG indicators for urban sustainability in Hainan, integrating regional specifics into assessments. Several studies (Yu et al., 2025; Jia et al., 2024; Liu et al., 2024; Liu et al., 2023; Chang et al., 2023; Han et al., 2022; Huang et al., 2021) explore city-specific indicators to evaluate progress toward SDG achievement. Global research, such as Basu et al. (2024), Mondal et al. (2024), and Ulpiani et al. (2024), extends this practice worldwide. In South Asia, Hussain et al. (2024) analyze the impact of climate change on Indian urban areas, advocating for city-level research to address regional disparities. Hossen et al. (2024) focus on urban sustainability challenges in Bangladesh, emphasizing infrastructure deficits and environmental degradation. Shah et al. (2023) argue that weak urban governance exacerbates sustainability inequalities, particularly in rapidly urbanizing regions. Bai et al. (2021) highlight the challenges of implementing SDG monitoring in developing cities, stressing the need for improved governance and data systems. However, studies based on SDG indicators in countries like Pakistan remain scarce.

Existing studies on urban sustainability in Pakistan highlight the importance of SDG-aligned indicators for assessing city performance. Research on cities in Punjab and Islamabad emphasizes gaps in meeting SDG goals, using social and statistical frameworks to measure development (Ahmad et al., 2023; Khan et al., 2022). Remote sensing analyses in Islamabad show how unchecked urban sprawl affects environmental health, stressing the need for spatial indicators under SDG 11 (Raza et al., 2021). Lahore's compact city approach aligns with SDG goals on resource efficiency, while broader studies identify

environmental trade-offs related to urbanization and SDG 13 (Ali et al., 2022; Shah et al., 2023). GIS-based evaluations of migration and resilience enhance localized SDG monitoring frameworks, highlighting the integration of socio-economic and environmental indicators (Hussain et al., 2024; Zafar et al., 2023). These studies stress the need for systematic data collection and governance reforms for effective SDG-aligned urban sustainability assessments.

The existing body of literature highlights the critical importance of localizing SDG frameworks to address regional and intra-regional disparities effectively. While global and national-level studies provide valuable insights, there is a significant gap in city-specific analyses, particularly in the context of developing regions like Punjab. The reviewed studies collectively emphasize the necessity of localized governance, robust data collection, and targeted interventions to improve sustainability outcomes. This study aims to fill these gaps by offering a comparative analysis of SDG-aligned performance indicators across Punjab's six major cities, contributing valuable insights to both academic discourse and policymaking practices.

Material and Methods

Data Acquisition

Time series data for Punjab's six major cities was obtained from sources like District Census Reports, Punjab Development Statistics (2003–2023) and environmental statistics from The Urban Unit and PHA. Data on electricity and water consumption came from DISCOs and WASA, supplemented by open data platforms. Missing data were addressed using standard imputation techniques to ensure reliability, enabling a comprehensive evaluation of city sustainability.

SDG Aligned Indicators

A set of SDG-aligned performance indicators was developed to assess the sustainability dimensions of six major cities in Punjab. These indicators cover key areas: cultivated area for food security (SDG 2: Zero Hunger), water consumption for clean water access (SDG 6: Clean Water and Sanitation), electricity consumption for energy demand (SDG 7: Affordable and Clean Energy), and economic productivity through GDP, employment, and industrial activity (SDG 8: Decent Work and Economic Growth). Urban infrastructure, including road length, green spaces, cultural amenities, and safety, is linked to SDG 11 (Sustainable Cities and Communities). Environmental pressures such as air quality, climate factors, and population density connect to SDG 13 (Climate Action), while crime rates address social justice and stability, tied to SDG 16 (Peace, Justice, and Strong Institutions).

Table 1
Elaborating performance indicators aligned with the SDGs

Indicator	Previous studies used this	Indicator	Previous studies used this
GDP	Huang, L., Yan, L., & Wu, J. (2016). Mendoza, O. M. V. (2017).	No. of Cinemas	Pavkovic, V., Karabaševic, D., Jevic, J., & Jevic, G. (2021)
Population	Sharifi, A. (2021)	No of universities	Sharifi, A. (2021)
Factories	Du, M., Zhao, M., & Fu, Y. (2020). Shmelev, S. E., & Shmeleva, I. A. (2018).	Electricity consumption	Huang, L., Wu, J., & Yan, L. (2015).
Employment	Du, M., Zhao, M., & Fu, Y. (2020).	Water consumption	Ghalib, A., Qadir, A., & Ahmad, S. R. (2017).

Road Length	Verma, P., & Raghubanshi, A. S. (2018)	$PM_{2.5}$ discharged	Huang, B., & Wang, J. (2020)
Cultivated Area	Huang, L., Wu, J., & Yan, L. (2015).	NO_2 discharged	Phillis, Y. A., Kouikoglou, V. S., & Verdugo, C. (2017)
Forest area	Michalina, D., Mederly, P., Diefenbacher, H., & Held, B. (2021)	PM_{10} discharged	Huang, L., Yan, L., & Wu, J. (2016)
No of parks	Lee, Y. C., & Kim, K. H. (2015)	O_3 discharged	Rada, E. C. (2014)
Density of population	Phillis, Y. A., Kouikoglou, V. S., & Verdugo, C. (2017	Rainfall	Yigitcanlar, T., Dur, F., & Dizdaroglu, D. (2015
No. of accidents	Mapar, M., Jafari, M. J., Mansouri, N., Arjmandi, R., Azizinezhad, R., & Ramos, T. B. (2020)	Temperature	Malah, A., & Bahi, H. (2022)
No of crimes	Gonzalez-Garcia, S., Manteiga, R., Moreira, M. T., & Feijoo, G. (2018)		

In the first stage, a descriptive comparative analysis (bar charts) is used to compare each city's performance across 20 sustainability indicators, offering a clear visualization of disparities and trends (Penuel et al., 2020; Johnson et al., 2018). The second stage applies Principal Component Analysis (PCA) to reduce dimensionality, producing composite dimensions based on factor loadings. These loadings are multiplied by the original indicator values to compute weighted scores, which are summed for each dimension (Shamim & Rihan, 2024; Li et al., 2023). Finally, Exploratory Data Analysis (EDA) with visual tools (heatmaps) compares cities' performance across dimensions, providing insights into their strengths and weaknesses, as shown in Figure 1.

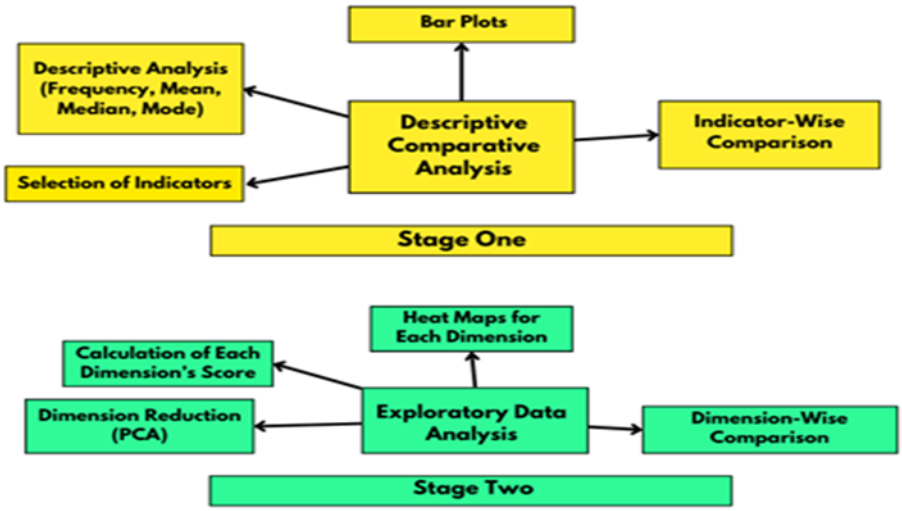

Figure 1: Depicting the overview of methodology

Indicator-wise Analysis

Each indicator has a table showing its mean and standard deviation across cities.

Table 2
GDP, population, employment and number of factories across cities

Indicator →	GDP Performance		Population Performance		Employment Performance		Factories Performance	
District	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Bahawalpur	847	341	673200	129701	15782	2908	314	97
Faisalabad	3623	1317	2906250	426771	140744	48142	1401	627
Lahore	12449	5312	9834200	2187520	157475	26376	1971	529
Rawalpindi	2372	811	1910005	240441	30319	6243	263	60
Multan	2102	741	1689383	229571	39463	6194	373	91

Sargodha	756	254	610700	69954	41960	6559	351	104

Table 2 highlights disparities in GDP, employment, population, and number of industries across cities in Punjab (2003–2022). Lahore is a provincial capital and with its diverse economy it leads in GDP, employment, population, and factory numbers, driven by strong industrial and services sectors' activities (Gu et al., 2022). Faisalabad follows with robust but moderately variable GDP and employment levels, reflecting its dependence on textile industry and limited diversification (Ali & Ahmad, 2022; Murdoch, 2018)). Rawalpindi and Multan demonstrate steady outputs, moderate employment, stable population growth, and balanced industrial activity due to their diversified but less competent economies than Lahore (Eraydın, 2017).. Bahawalpur's agricultural dependency results in lower GDP, employment, and population levels, with higher variability in economic indicators (Henderson et al., 2012). Sargodha, with minimal variability across indicators, reflects stagnation and limited urbanization, highlighting its underdeveloped economic profile.

Table 3

Total area, road length, cultivation area & forest area

Indicator	**Total Area**		**Road Length**		**Cultivation area**		**Forest area**	
District	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Bahawalpur	24830	0.0	2610	404	438	12	1023	1160
Faisalabad	5856	0.0	3340	479	491	25	1663	4117
Lahore	1772	0.0	1257	47	107	8	1	0.0
Rawalpindi	5286	0.0	3717	53	247	18	102	28
Multan	3720	0.0	2135	300	306	3	3	2
Sargodha	5864	0.0	3562	1073	508	16	1	0.0

Table 3 highlights disparities in total area, road length, cultivation, and forest cover across Punjab's cities. Rawalpindi leads in road length due to investments near Islamabad (Ahmad et al., 2020), while Lahore, with the lowest mean, relies on public transport to reduce congestion (Hussain et al., 2019). Faisalabad's roads support industry, and Multan benefits from the M-5 Motorway, while Bahawalpur enhances agricultural links under CPEC. Sargodha, despite uneven development, integrates into trade corridors (Ali et al., 2023). Sargodha also leads in cultivated area, while Faisalabad shows variability due to diverse farming. Urbanization limits cultivation in Rawalpindi and Lahore (Malik et al., 2015). Bahawalpur has the largest forest cover, though unevenly distributed (Ahmad et al., 2015). Lahore's deforestation and Faisalabad's fragmented forests reflect urbanization, while Sargodha and Multan prioritize agriculture. Sustainable policies are needed to balance urbanization, agriculture, and forest management.

Table 4

Showing number of cinemas, universities and parks

Indicator→	**Cinema Performance**		**Universities Performance**		**Parks Performance**	
District	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Bahawalpur	2.25	2.10	2.35	1.23	13.15	1.63
Faisalabad	12.25	8.17	4.25	1.37	18.75	4.87
Lahore	19.95	3.46	24.95	8.04	40.50	4.22
Rawalpindi	10.65	5.41	2.85	0.99	34.35	3.59
Multan	7.20	3.14	3.40	1.10	27.95	4.05
Sargodha	4.05	1.67	1.65	0.81	13.25	2.10

Table 4 highlights disparities in parks, cinemas, and universities across cities. Lahore leads in parks, reflecting its emphasis on green spaces amid urbanization (Hanif, 2024). Rawalpindi follows due to its proximity to Islamabad, while Multan balances green space with urban growth. Faisalabad's park distribution is uneven, and Bahawalpur and Sargodha have fewer parks due to limited funds (Ahmad et al., 2015). Lahore also leads in cinemas, showcasing its role as an entertainment hub (Shah, 2024), while Faisalabad and Rawalpindi have moderate availability. Multan, Sargodha, and Bahawalpur show minimal

cinema access, with an overall decline due to alternative digital entertainment (Khan et al., 2015). Lahore's academic prominence is evident in its highest number of universities, followed by Faisalabad and Multan, while Bahawalpur, Rawalpindi, and Sargodha lag behind, reflecting varying investment priorities (Khan et al., 2020; Malik et al., 2018). These disparities highlight the need for equitable education and infrastructure policies.

Table 5
Showing electricity and water consumption

Indicator→	Electricity Performance		Water Performance	
District	**Mean**	**SD**	**Mean**	**SD**
Bahawalpur	739.40	261.569	183.40	90.844
Faisalabad	5650.80	1701.510	408.60	121.582
Lahore	12122.50	7294.260	510.35	25.471
Rawalpindi	8124.15	4085.780	272.75	127.854
Multan	615.80	66.420	123.80	42.201
Sargodha	541.60	76.181	150.35	59.908

Table 5 highlights disparities in electricity and water consumption across Punjab's cities, driven by economic and industrial activity. Lahore leads in electricity consumption due to its large population and economic base (Malik et al., 2017). Rawalpindi's demand is tied to its service sector, while Faisalabad's stems from its textile industry (Khan et al., 2019). Bahawalpur, Multan, and Sargodha show lower and stable electricity use, reflecting their agricultural economies and limited industrialization (Ahmad et al., 2015). For water, Lahore exhibits the highest consumption with low variability, while Faisalabad's demand is water-intensive due to its industry. Rawalpindi shows moderate water use but relies heavily on depleting groundwater. Bahawalpur, Multan, and Sargodha depend less on public water supplies, typical of rural regions. These trends underscore the need for policies promoting resource efficiency and balanced allocation across Punjab's diverse cities.

Table 6
PM2.5 discharge, NO2 discharge, PM10 discharge, PM2.5 discharge, NO2 discharge & PM10 discharge

Indicator→	PM2.5 discharge		NO2 discharge		PM10 discharge	
District	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Bahawalpur	249	273	3	2	170	29
Faisalabad	184	34	31	6	92	19
Lahore	141	19	21	5	101	17
Rawalpindi	76	13	24	6	42	11
Multan	195	15	25	4	47	12
Sargodha	132	46	13	4	95	9
Indicator→	**PM2.5 discharge**		**NO2 discharge**		**PM10 discharge**	
District	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Bahawalpur	43	15	211	136	34	0.7
Faisalabad	63	11	433	109	32	1
Lahore	97	10	674	152	31	0.6
Rawalpindi	94	24	124	332	29	0.8
Multan	66	12	223	82	32	1
Sargodha	95	12	502	170	34	6

Table 6 highlights disparities in air quality, temperature, and rainfall across Punjab's cities. Bahawalpur records the highest PM2.5 levels due to its desert proximity, while Faisalabad and Lahore face air quality challenges from industrial activity and urbanization (Malik et al., 2018; Khan et al., 2019). Rawalpindi shows stable air quality, with moderate fluctuations in Multan and Sargodha linked to agriculture (Ahmad et al., 2015). Faisalabad leads in NO2 emissions due to its industrial base, while Lahore and Rawalpindi face high levels from traffic congestion. Bahawalpur, with minimal

industrialization, has the lowest NO2 levels. PM10 levels are highest in Bahawalpur, followed by Faisalabad and Lahore. Ozone levels peak in Lahore and Rawalpindi, driven by traffic and industry. Rainfall is highest in Rawalpindi due to orographic effects, while Bahawalpur and Multan show low, stable rainfall. Bahawalpur experiences extreme temperatures, while Sargodha has seasonal fluctuations, reflecting geography and industrialization impacts.

Table 7
Showing no. of accidents, crime rate & population density

Indicator→	Accidents Performance		Crime Performance		Density Performance	
District	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Bahawalpur	140.70	35.686	9205.95	4025.274	27.11	5.22
Faisalabad	198.75	50.926	32232.90	7582.075	496.29	72.88
Lahore	640.95	122.312	181123.00	28313.700	5549.77	1234.49
Rawalpindi	373.85	39.317	23477.80	8388.142	361.33	45.49
Multan	106.35	23.591	17376.30	4575.502	454.14	61.71
Sargodha	217.70	43.225	14520.00	1907.846	104.14	11.93

Table 7 reveals notable differences in accident rates, crime rates, and population density across Punjab's cities. Lahore has the highest accident rate (640.95), driven by traffic congestion and road safety issues (Malik et al., 2015), followed by Rawalpindi and Faisalabad, while Multan has the lowest (106.35), reflecting less congestion. Crime rates are highest in Lahore, attributed to urban challenges and economic disparity (Khan et al., 2020), with Faisalabad and Rawalpindi also showing elevated rates. In contrast, Sargodha and Multan experience lower, more consistent crime, and Bahawalpur has moderate crime. Population density is highest in Lahore due to rapid urbanization (Ahmed et al., 2021), followed by Faisalabad and Rawalpindi, while Sargodha has a lower density, indicating more rural characteristics. Multan and Bahawalpur show intermediate densities, with urbanization pressures in Multan and dispersed settlements in Bahawalpur. High variability in Lahore's density points t overcrowded slums and infrastructure challenges (Chaudhry et al., 2020).

Dimension-wise Analysis

Table 8
The dimension wise distribution and weights of indicators

Dimensions	Indicators	Weights (%)
Economy	GDP	7.09
	Population	7.02
	Factories	8.94
	Employment	9.50
Infrastructure	Total Area	7.09
	Road Length	8.44
	Cultivated Area	7.57
	Forest area	6.63
Cultural Factors	No of parks	5.67
	No of cinemas	5.46
	No. of Universities	7.07
Resource Consumption	Electricity	7.82
	Water	7.99
Environment Factors	PM2.5 discharged	4.57
	NO2 discharged	7.48
	PM10 discharged	8.35
	O3 discharged	6.98
	Rainfall	7.15
	Temperature	6.78
Social Factors	No. of Accidents	8.27

	No. of Crimes	9.69
	Density of Population	9.51

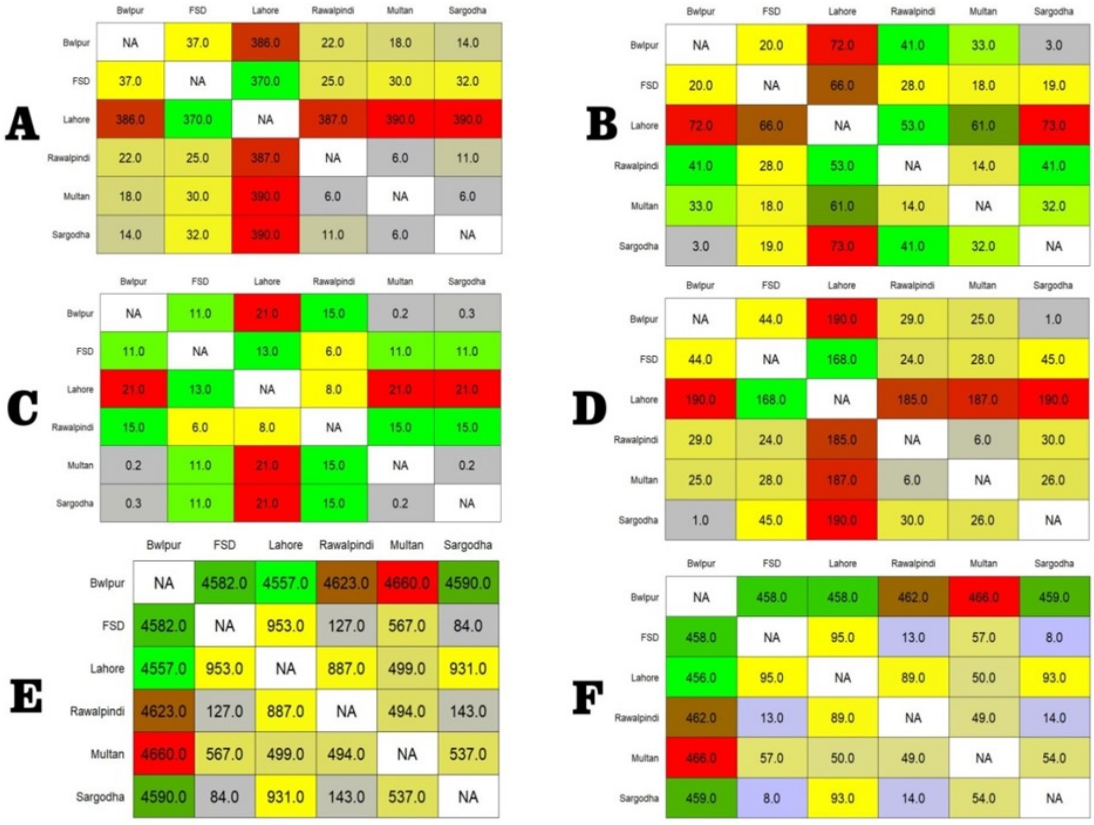

Figure.2: Depicting the dimensions across cities: A;social factors, B;cultural attraction, C;resource consumption, D;Economy, E;Infrastructure, F;Environment Pressure

These heat-maps in Fig.2. represent city comparisons across six dimensions. Fig. 2A illustrates similarities in population density, crime rates, and accidents, where Lahore and Sargodha differ due to economic disparities and congestion, while Multan and Rawalpindi are more alike (Hipp et al., 2021; Sánchez González et al., 2021). Fig. 2B highlights Lahore's cultural diversity, especially compared to Bahawalpur and Sargodha, while these two cities are more similar, with Faisalabad, Rawalpindi, and Multan showing moderate cultural differences. Fig. 2C reveals that Lahore has the highest resource consumption due to its larger population and economy, while Bahawalpur and Multan show minimal differences. Fig. 2D shows economic differences, with Lahore standing apart from Bahawalpur and Sargodha, reflecting their rural nature, while Faisalabad and Rawalpindi are closer to Lahore due to more dynamic economies. Fig. 2E shows Sargodha and Faisalabad sharing similar infrastructure, with Multan differing due to recent road expansions (Jaleel et al., 2023). Finally, Fig. 2F shows Faisalabad and Sargodha sharing similar environmental conditions, while Multan and Bahawalpur show similarities due to desert proximity and agricultural land.

Discussion

This study examines socio-economic, environmental, and infrastructure disparities across six Punjab cities from 2003 to 2022. Lahore leads in GDP, industrial activity, population density, and resource consumption due to its metropolitan scale, while

Sargodha and Bahawalpur, with rural agricultural economies, show lower economic activity and stable environmental pressures. Multan and Rawalpindi, though large, lag behind in several benchmarks. These disparities highlight the need for targeted policies, particularly in managing congestion, improving infrastructure, and balancing industrial growth with environmental sustainability. Lahore's challenges include high crime rates, accidents, and pollution, necessitating sustainable urban planning with better infrastructure and green spaces. Sargodha and Bahawalpur, with more ecological stability, have potential for agricultural innovation and eco-tourism. Faisalabad, Rawalpindi, and Multan need policies addressing industrialization pressures while focusing on resource consumption and air quality.

Recommendations

In conclusion, region-specific, integrated policies are essential to address the diverse challenges faced by urban and rural cities, fostering balanced development. Key recommendations include:

Sustainable Urban Planning: Focus on green spaces, public transport, and industrial regulations in Lahore and Rawalpindi to mitigate congestion and pollution (Malik et al., 2015; Hussain et al., 2019).

Economic Diversification: Promote sustainable industrial practices and diversification in Faisalabad's textile sector (Ali & Ahmad, 2022).

Agricultural Sustainability: Implement climate-smart agriculture and water-efficient practices in Sargodha and Bahawalpur (Bhatti et al., 2019).

Education and Infrastructure: Enhance education and infrastructure in smaller cities like Sargodha and Bahawalpur (Khan et al., 2020; Ahmed et al., 2021).

Air Quality Control: Strengthen air quality standards in Lahore, Faisalabad, and Rawalpindi (Khan et al., 2019).

Water Management: Invest in water-saving technologies in Lahore and Faisalabad (Siddiqui et al., 2017).

Inter-City Connectivity: Improve transportation and digital networks to foster balanced growth (Jaleel et al., 2023).

Climate Adaptation: Promote climate-resilient practices in Bahawalpur to combat droughts and water scarcity (Ahmad et al., 2015).

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