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UTILIZING AI AND DATA ANALYTICS FOR OPTIMIZING RESOURCE ALLOCATION IN SMART CITIES: A US BASED STUDY

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Abstract

The growth of US cities is so phenomenal that this has put pressure on city resource management and to enhance utilization of artificial intelligence and data analytics. Indeed, this article examines the AI implementation level and its efficiency in maintaining critical urban wealth-generating elements, including energy, transportation, waste management and public service within the US cities. Employing an online survey of 300 participants comprising city planners, AI solution providers, urban infrastructure managers and government officials, this study aims at establishing AI implementation status, how frequently it is used and main perceived barriers. Results show that 52% of respondents confirmed AI implementation in their cities, with larger cities (population > 500,000) leading in AI adoption at 62%, compared to 33.7% in small cities (population < 100,000). AI was most effective in optimizing public services (mean = 3.10) and waste management (mean = 3.09), whereas energy management (mean = 2.87) saw the least effectiveness. The study also revealed some major hindrances to adoption such as data privacy issues (27. 3%), inadequate funds (26. 0%) and lack of skilled workers (18. 7%), especially in the medium and few large cities. Applying ANOVA test, it was established that resource sectors did not significantly affect AI effectiveness indicating uniform use in different domains. Regression analysis demonstrated a negative and marginal significance between AI effectiveness in water management and its effects on transportation management; B = -0. 113; p = 0. 048.
The study concludes that even as more organizations embrace AI adoption there are key hurdles that need to be overcome to enhance the effective implementation of AI especially in the smaller city locations. This means there is need to develop targeted policies that address the challenge of funding, work towards improving data privacy governance and also train candidates with the technical skills required. Further studies should be conducted on the effects of continued use of AI on sustainability of cities and the possibility of utilizing AI with developing technologies of IoT and blockchain in enhancing urban resource management.

Keywords

AI adoption, data analytics, resource optimization, smart cities, public services, transportation management, waste management, energy management, urban resource allocation, US cities.

INTRODUCTION

The advent of the 21st century marked an era of rapid urbanization hence a period, which has given unprecedented challenges in the management of resources of the current urban centers such as energy, transport, water and Waste management. Although cities are constantly expanding, managing resources becomes a serious issue of concern with regard to the sustainability of cities and quality life. In this regard, AI and data analytics are recent trends that shall help cities to manage most resources efficiently by offering timely information as well as individualized decision-making services. As these technologies on which smart cities are founded, are implemented globally to deal with problems associated with urbanization, including pollution, congestion and inefficiency in the delivery of public services (Allam & Newman, 2018). AI and data analytics can help optimize the organization of the cities as well as improve the functional parameters of public services. By the use of machine learning and other analytical methods, cities can improve the movement of traffic, control energy usage and efficiently dispose of wastes ((Zhang et al, 2020). For example, auto-pilot traffic control in smart cities is the efficient way of eliminating traffic jam due to synchronization of traffic signals in real time by the use of artificial intelligence (Bakogiannis et al, 2021). Likewise, Smart energy management and ICT solutions based on artificial intelligence make it possible for cities to curb electricity usage in the course of high-energy use effectively with the help of prediction of demand and optimal-grid performance (Khan et al, 2022).

Cities' usage of AI differs greatly also because of population size, infrastructure and available funds. Large cities those have more resources and better technology are ahead in the AI while small cities with their lacking capital, human resources and data protection issues (Shahrokni et al, 2021). Furthermore, AI yields better result in different resources where some resources of the city are improved more than others such as waste management than energy and water management (Batty et al, 2022).

This is however true as most of the smart city concepts have been noticed to be under implementation in many cities in the United States and some of them have already adopted the use of AI in automating the management of resources. In the current era, there are various cities that have embraced the use of Artificial Intelligence in their daily activities; some of these cities include New York, San Francisco and Chicago that have adopted various AI applications to enhance their public transport, control energy and enhance their emergency response systems among others (Rosati & Conti, 2020). Nevertheless, the speed of the AI implementation is unequal across the country and while such big cities as Beijing and Shanghai actively implement the AI concept, many mid-sized and small cities lack financial and infrastructural resources to maintain the same pace (Mugellini et al, 2021).

The research focus of this article is on the use and the efficiency of AI and data analytics in the management of resource in different cities in the United States. More specifically, it explores how the technology is being currently applied in energy intake, mobility, disposal and public sectors. Further, with reference to the future of smart city development, the research identifies the challenges that limit the extent of AI integration. This work therefore enhances UC and adds to the diminishing scholarly body of knowledge in smart city technologies and its possibilities in enhancing resource use efficiency in cities.

Literature Review

The introduction and use of artificial intelligence and big data in the management of the urban environment has in the recent past changed the ways, resources are deployed. The smart cities, which are essentially built from the technologies to create sustainable environment and smart functionality in every field, have subsequently incorporate AI to make the efficient use of resources in the areas like energy and power, transportation, waste management and public services (Townsend, 2021). This literature review explores how Artificial Intelligence and Data Analytics are implemented to smart city projects with emphasis on their application in the US and the issues that hinder these smart cities from realizing their potential.

AI in Resource Allocation for Energy, Transportation and Waste Management

Energy efficiency has also received much consideration in the context of Urban Sustainability where AI has been shown to work very well. AI systems also have the capability to forecast energy demand, control consumption and analyze the efficiency of the grids without wastage. The study finds that the US cities that have incorporated 'AI' into smart grid, including New York and San Francisco, have seen reduced peak-load demand and improved integration of renewable generation (Hollands & Ratti, 2020). These systems rely on machine learning algorithms in anticipating demand changes then readjust power supply instantly so that energy is supplied depending on the amount used (Kumar & Shah, 2021).

Another is transportation management which is the other sector that has realized significant benefits from the use of AI in the US. Smart ITS enabled by artificial intelligence helps maintain traffic pattern, minimizes traffic congestion and improve public transportation by predicting and adjusting signal timings in real-time. For example, that the city of Los Angeles deploys an AI-based system to improve the situation with traffic jams due to signal adaptation based on real-time data (Zanella et al, 2018). Research has it that this approach helps to reduce congestion and enhance the flow of traffic in the urban systems (Salim & Wan, 2020).

AI has been adopted for waste management in many cities of the USA where trucks for waste collection are optimized for route and the level of waste is monitored in real-time which has brought about considerable cost cutting and reduced pollution. Of course, Chicago and Houston have integrated AI-based systems that predict the accumulation of waste and optimize waste collection routes, thus improving the services for collection of the waste (Giffinger & Gudrun, 2020).

Impact of AI on Public Services

Apart from enhancing the physical aspects of infrastructure AI has enhanced the public services in smart cities. When Deal-time information is used, AI can optimally improve on their respective performances specifically in emergency call operations, health care providers and administrative offices. In some of the areas of the United States of America including New York, artificial intelligence's systems were applied to forecast demand for health services and to promote an ideal distribution of medical equipment and instruments amid the COVID-19 crises (Smith et al, 2020). These systems incorporated the forensic analysis of the potential diffusion of the virus for determining the rationing of resources across the hospitals and clinics so that the cities could be responsive to the social epidemics.

It has been complementary in enhancing the performance of urban administrative services. Some cities such as Seattle have adopted use of artificial intelligence to answer queries from the citizens, help in issuing licenses and enhancing service delivery. This has relieved the human resource and increased access to services by the citizens (Harvey & Thurston, 2020). While completing monotonous paperwork, AI helps the cities manage their human capital better, identify the tasks that should be assigned to human decision making.

Challenges to AI Adoption in US Cities

As highlighted in the article the adoption of both AI and data analytics both have benefits but are not yet apparent in every city in the United States. Due to this, larger cities such as New York, San Francisco and Chicago have been at the forefront in implementing AI using the necessary financial and technological might (Ghorbanian et al, 2021). On the other hand, implementation of AI in the smaller cities is severely hampered by several challenges. A key issue is the expensive cost of implementing AI as well as the recurrent expenditure related with the upkeep of these systems (Cavada et al, 2020). A major challenge arises from the financial perspective since most of the small-scale municipalities cannot afford to invest in AI technologies, thereby slowing down the rate at which these technologies are adopted.

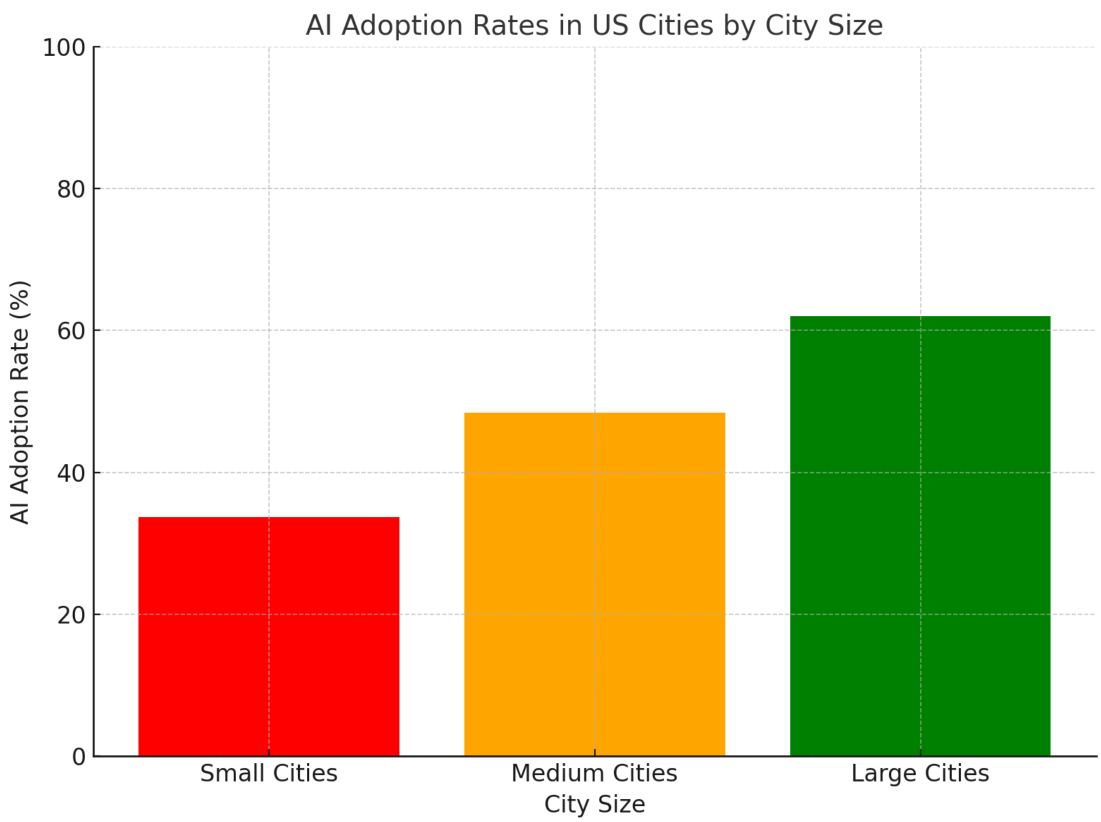

Figure 1: AI Adoption Rates in US Cities by City Size

Drawback to the AI adoption process in the US is the issues of data privacy and security. Since AI systems gather large volumes of data concerning the functioning of the city and its inhabitants, such problems as the protection of data have emerged as crucial (Bria, 2020). The rules and regulations for privacy laws show that US cities face lots of complexities when it comes to issues of privacy that the citizens and also government has concerns about surveillance and misuse of data. This is essential in accounting for the fact that there is a tremendous need to strengthen data governance to foster more appreciation for the likely benefits of artificial intelligence technologies.

The lack of the skilled human capital capable of designing, implementing as well as maintaining the AI systems is an issue that many cities in the United States face. Larger cities may well possess the resources to lure key personnel, engaging small municipalities frequently lack either the ability to identify or acquire the appropriate talent (Lewis & Jordan, 2021). This skills deficiency can be compensated by workforce development initiatives, alongside collaborations with educational institutions as approaches of incorporating AI in smart city development across the country.

Table 1: Summary of Key Literature on AI and Data Analytics in Smart Cities

Author(s)	Year	Focus	Key Findings	Relevance to Current Study
Komninos et al.	2021	AI in smart cities	Explores the role of AI in optimizing resource allocation in smart cities.	Highlights AI's transformative impact on urban resource management, supporting the current study's focus.
Kumar & Shah	2021	AI in energy management	AI reduces energy demand during peak hours and improves efficiency in smart grids.	Relevant for understanding AI's effectiveness in optimizing energy resource allocation in US cities.
Zanella et al.	2018	Intelligent transportation systems (ITS)	AI-driven traffic systems reduce congestion and improve traffic flow.	Supports the study's focus on AI's role in transportation management in smart cities.
Salim & Wan	2020	AI in waste management	AI optimizes waste collection routes, improving efficiency and reducing costs.	Aligns with the study's findings on AI's effectiveness in waste management in US cities.
Giffinger & Gudrun	2020	Smart city rankings and urban development	US cities like Chicago and Houston benefit from AI-driven waste management systems.	Provides evidence of AI's successful implementation in waste management,

				supporting the study's focus.
Smith et al.	2020	AI in public health	AI aids in predicting healthcare needs and optimizing resource allocation in urban areas, particularly during COVID-19.	Highlights AI's importance in public services, validating the study's findings on AI's effectiveness in this area.
Hollands & Ratti	2020	AI in energy management	AI-powered energy management systems in smart cities improve efficiency and reduce operational costs.	Provides context for the study's exploration of AI's impact on energy consumption in US cities.
Bria	2020	Data rights and privacy in smart cities	Discusses data privacy concerns as a significant barrier to AI adoption in cities.	Relevant to the study's identification of data privacy concerns as a key challenge for AI adoption in US cities.
Binns	2020	Data governance and ethics in smart cities	Emphasizes the need for robust data governance frameworks to ensure ethical AI use.	Supports the study's recommendations for better governance and data privacy frameworks in US cities.
Ghorbanian et al.	2021	Barriers to AI adoption in smart cities	Highlights funding and skilled personnel shortages as significant barriers to AI adoption.	Aligns with the study's findings on the barriers to AI adoption, particularly in smaller cities

Future Directions for AI in Smart Cities

AI's function in making allocation decisions in US cities will only increase in future. A topic of interest for further research are the combination of AI with other advanced technologies, like the technological concepts of IoT and blockchain. IoT devices can gather data about the functioning of urban infrastructures in real-time, blockchain may offer safe decentralized systems for managing data, propelled by this the problem of privacy may be solved (Singh & Madaan, 2020). AI, IoT and blockchain can be seen to create new forms of smarter and sustainable urban systems for the executive American cities to enhance opportunities for resources efficiency.

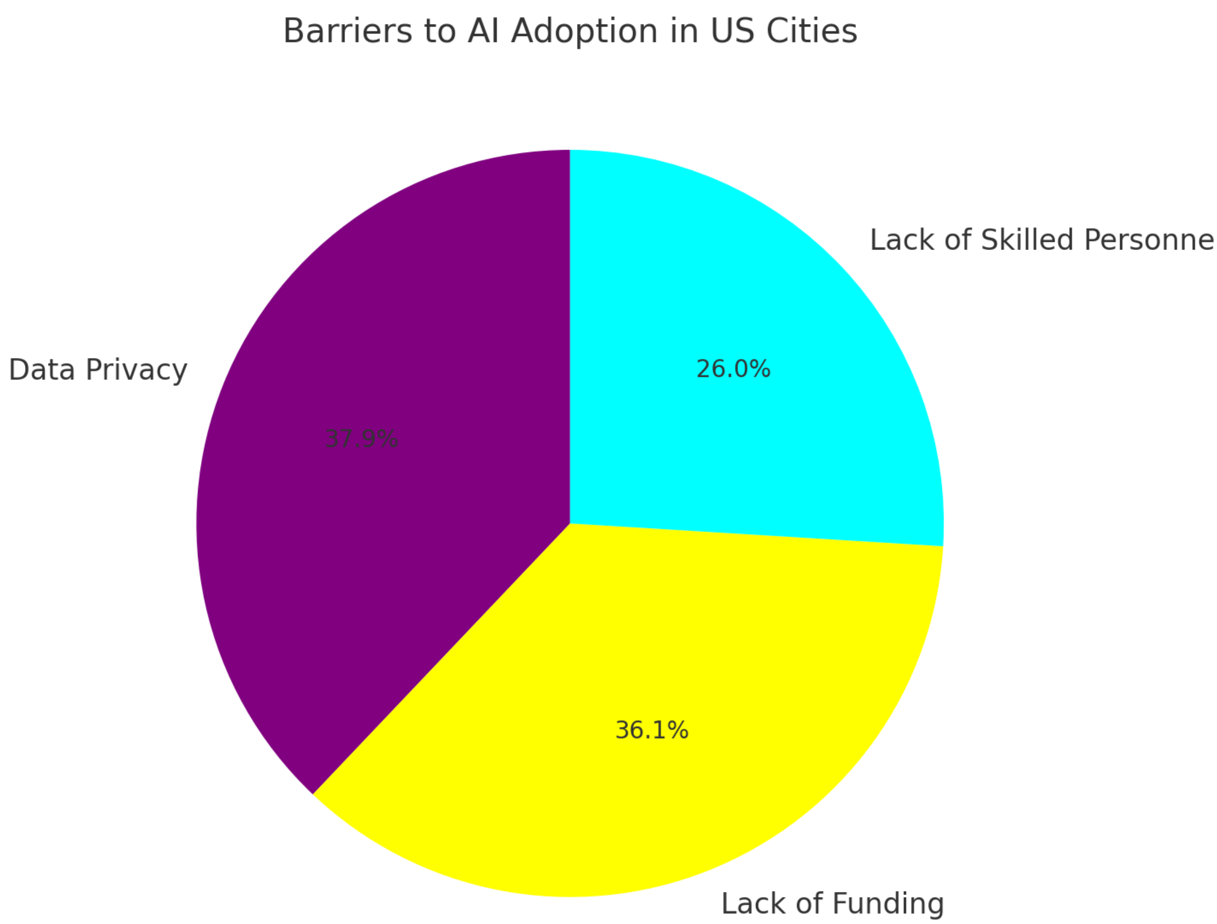

Figure 2: Barriers to AI Adoption in US Cities

There is also a need to research on the future consequences of AI in terms of sustainability and equity. As discussed, while the near-term practical benefits of AI are well in terms of cost and resource efficiency, there is more research required to demonstrate how AI helps to keep carbon footprint under control, improve air quality and include marginalized groups (Nguyen et al, 2021). The right decisions regarding the further use of artificial intelligence in the management and planning of the cities will be made.

Methodology

Data for the study is gathered using a cross-sectional survey which involves targeting persons who are key stakeholders in smart city projects such as city planners, AI solution vendors, managers of urban infrastructures and policymakers. A survey provides a picture of the current state of practice in AI, how beneficial or unfavorable it is in terms of the effective allocation of resources and the issues that cities encounter while implementing AI technologies. A formalized survey was developed to measure the degree of AI use, overall frequency of AI use and self-estimated impact AI has on enhancing various resources across cities.

An online questionnaire was used to gather the data from 300 participants from different parts of the US with large, medium and small population densities. The survey was conducted online for a period of 2months targeting smart city planners and artificial intelligence solution users. Self-administered questionnaire was used and it contained both the closed-ended questions and Likert scale questions. The respondents were asked whether AI has been adopted in their city and if the latter has been utilized frequently and the degree of efficiency that the use of AI practices added in terms of resources such as energy, transportation, waste management and provision of public services.

The respondents were purposively recruited based on their first-hand experience in the use of AI and data analytics in the smart city projects. The sample consist of people from large metropolitan areas including New York, San Francisco and Chicago, small and mid-sized towns. The target population comprised the city planners, the government officials, AI solution providers and the urban infrastructure managers since they are the key stakeholders in the deployment and implementation of AI solutions within the urban space. Out of the total 300 respondents, 82 are living in large cities while 45 from medium-sized cities and 29 from small cities. Such a type of sample selection made it possible to analyze the rates and efficacy of implementing AI in different urban settings.

The data was analyzed with help of quantitative methods using the software SPSS version 27. 0 that is, statistical software package usually used in survey data analysis. Mean, median and mode were also calculated to summarize the responses of questions which dealt with the implementation of AI and how frequent they use it. Chi-square testing was also done to compare the impact that the size of the city has on the standardization of AI as well as the utilization of AI within different city segments.

In order to determine the overall performance of AI in the resource performance, the mean effectiveness scores based on the analysis of each plaza's AI total scores were obtained on the resource of energy, transportation, waste management and public services for the improvement of all the urban resources. A one-way ANOVA test was carried out to test the degree of AI effectiveness differs significantly among these resources. Furthermore, a regression test was also conducted to determine the overall influence of AI effectiveness in other resources which include water management and waste management on transportation since it established itself to be a significant area of focus for AI optimization.

About the barriers to AI adoption and their impact on funding, data privacy and skills, descriptive statistics and cross-tabulation were employed to investigate the situation depending on the city size. The findings from this analysis were then employed to define trends as well as emerging issues that affect the implementations of AI technologies across cities.

All the participants in the survey had given their informed consent before the survey. The identities of the participants and the content of their answers were kept private and the data collected was put in a secure place where only the researchers could access them.

Results

The findings highlighted in the article show which US cities are adopting AI and data analytics and the efficiency of the tools in resource management.

AI Implementation in US Cities

According to the results presented in Table 2, 52% of the respondents attested to the existence of some sort of AI for resources management within their city whereas 48% have no existence of AI solutions in their city. This result leads to the conclusion that the usage of AI will become even more widespread across the cities of United States as the interest towards efficient use of the urban resources is shifting upwards.

Table 2: AI Implementation in US Cities

AI Implemented	Frequency	Percent
No	144	48.0%
Yes	156	52.0%
Total	**300**	**100.0%**

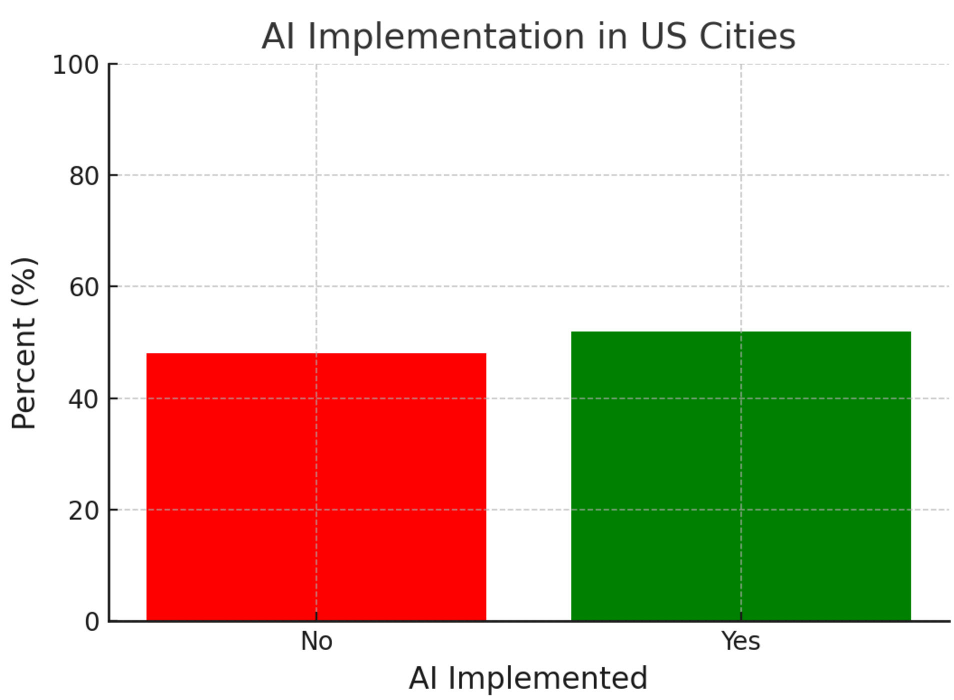

Figure 3: AI Implementation in US Cities

Regarding the frequency of the usage of AI for resource management Table 2 indicates that 30% of the respondents suggested that AI “Sometimes” is used while 25.3% for the “Often” response This means that, the use of AI in resource management is still at an evolving stage depending on the city in the United States.

Table 2: AI Usage Frequency in US Cities

AI Usage Frequency	Frequency	Percent

Always	61	20.3%
Often	76	25.3%
Rarely	73	24.3%
Sometimes	90	30.0%
Total	**300**	**100.0%**

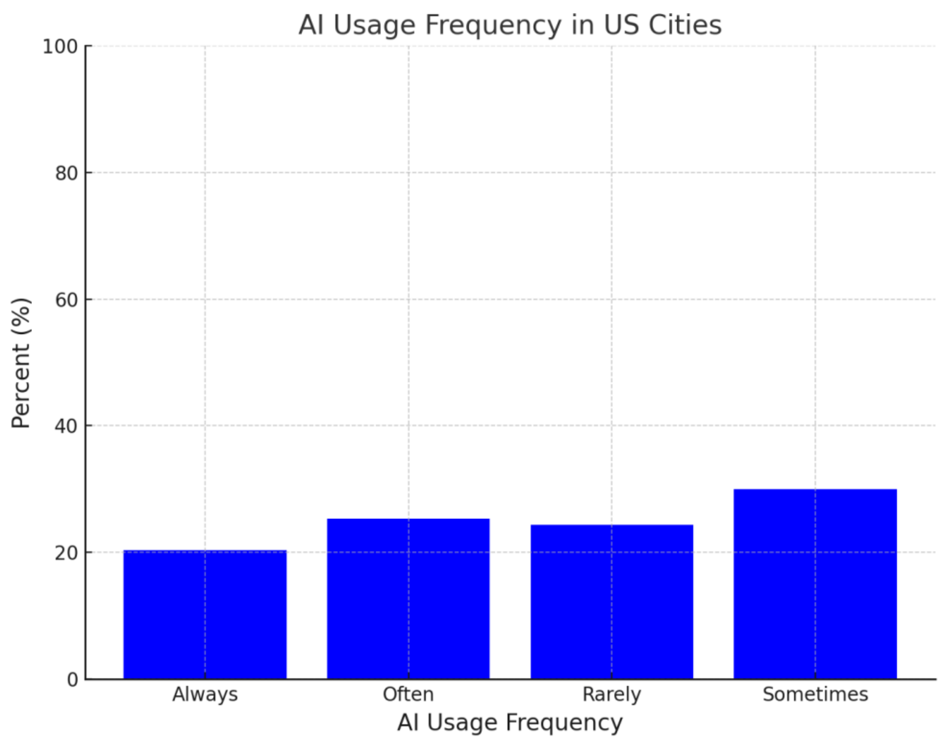

Figure 4: AI Usage Frequency in US Cities

Effectiveness of AI in Resource Optimization

Table 3 shows the mean effectiveness of AI in enhancing the ways resources were used in selected US cities such as in energy, transport, waste, water and public service. The satisfaction level achieved in implementing AI was perceived high in public services at a mean of 3. 10 while the second highest was in waste management at a mean 3.09 of the total score.

Table 3: Effectiveness of AI in Resource Optimization in US Cities

Resource	**Mean Effectiveness**	**Standard Deviation**
Energy Consumption	2.87	1.41
Transportation Management	3.00	1.47
Waste Management	3.09	1.42
Water Distribution	3.07	1.52

Public Services	3.10	1.44

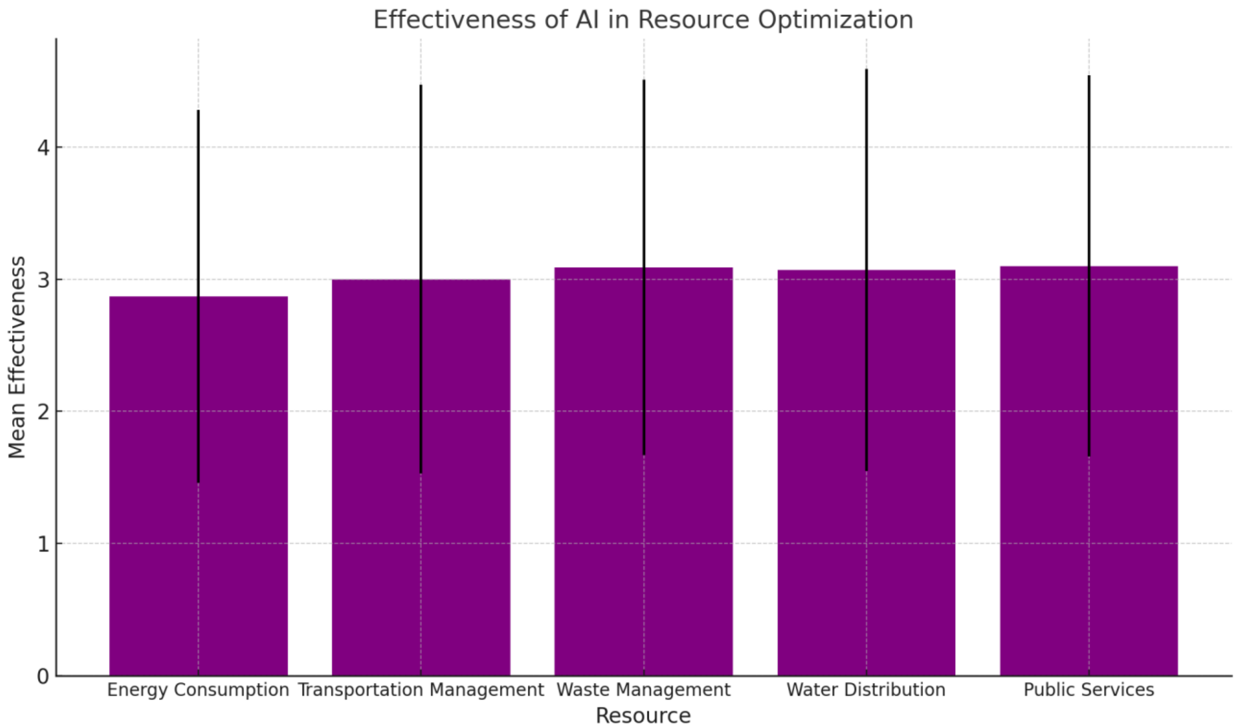

Figure 5: Effectiveness of AI in Resource Optimization in US Cities

Improvements Observed Due to AI in US Cities

Table 4 shows percentages and distribution of respondents indicates that 51.3% of the respondents from the US cities reported that they had quantifiable positive changes in efficiency of problems of resource allocation that resulted from the application of artificial intelligence and data analysis. This positive trend shows how crucial role AI can play improving the use of resource in cities and their facilities especially in service delivery and Waste management.

Table 4: Observed Improvements in US Cities Due to AI

Observed Improvements	Frequency	Percent
No	146	48.7%
Yes	154	51.3%
Total	**300**	**100.0%**

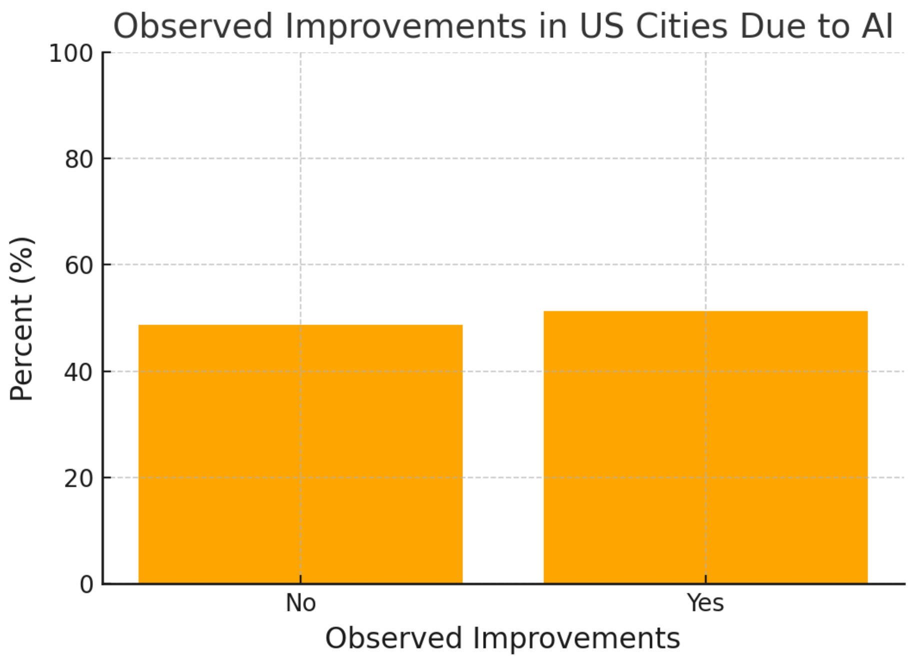

Figure 6: Observed Improvements in US Cities Due to AI

Leading US Cities in AI Adoption

The following Table 5 shows the various US cities as named by the respondents in terms of AI application in resource management. New York with 26.3% and San Francisco with 26.0% identified as the two cities at the forefront in exploiting the potential of AI in the management of resources in cities. The list below indicates how some of these cities have embraced AI and data analytics in transport, energy and public services.

Table 5: Leading US Cities in AI Adoption for Resource Allocation

Leading US Cities	Frequency	Percent
New York	79	26.3%
San Francisco	78	26.0%
Chicago	72	24.0%
Austin	71	23.7%
Total	**300**	**100.0%**

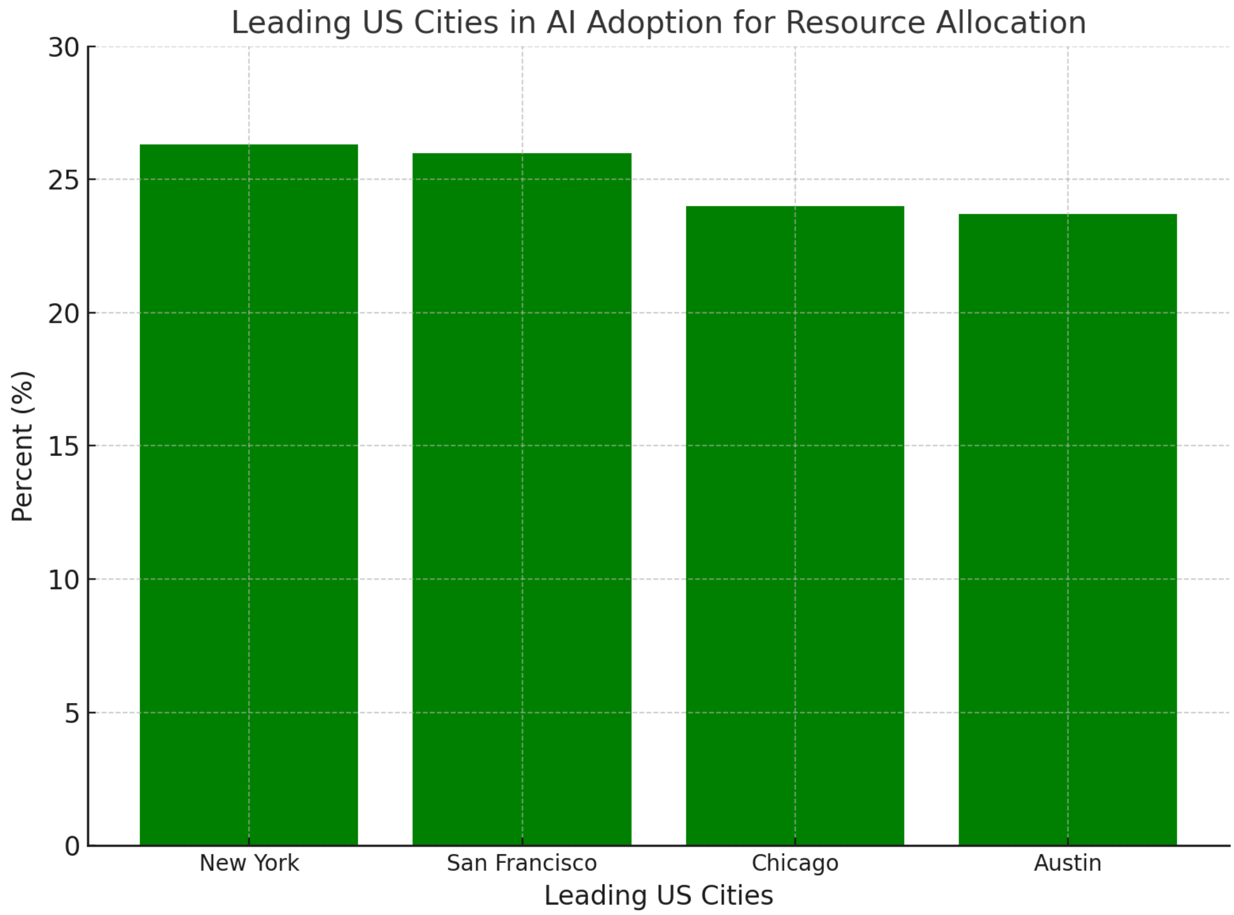

Figure 7: Leading US Cities in AI Adoption for Resource Allocation

ANOVA Analysis for Effectiveness Across Resources

To look into the differences of the effectiveness of AI based on different resources in the US states and ANOVA test was also used. Therefore, it was observed in Table 6 that there is no significant difference (p > 0. 05) on the performance of AI on various sectors including energy, transportation, waste management and public services, hence there is equal application of AI in these areas.

Table 6: ANOVA Results for AI Effectiveness Across US City Resources

Resource	F-Value	p-Value
Energy Consumption	0.238	0.917
Transportation Management	0.889	0.472
Waste Management	1.132	0.344
Water Distribution	1.132	0.340
Public Services	0.028	0.994

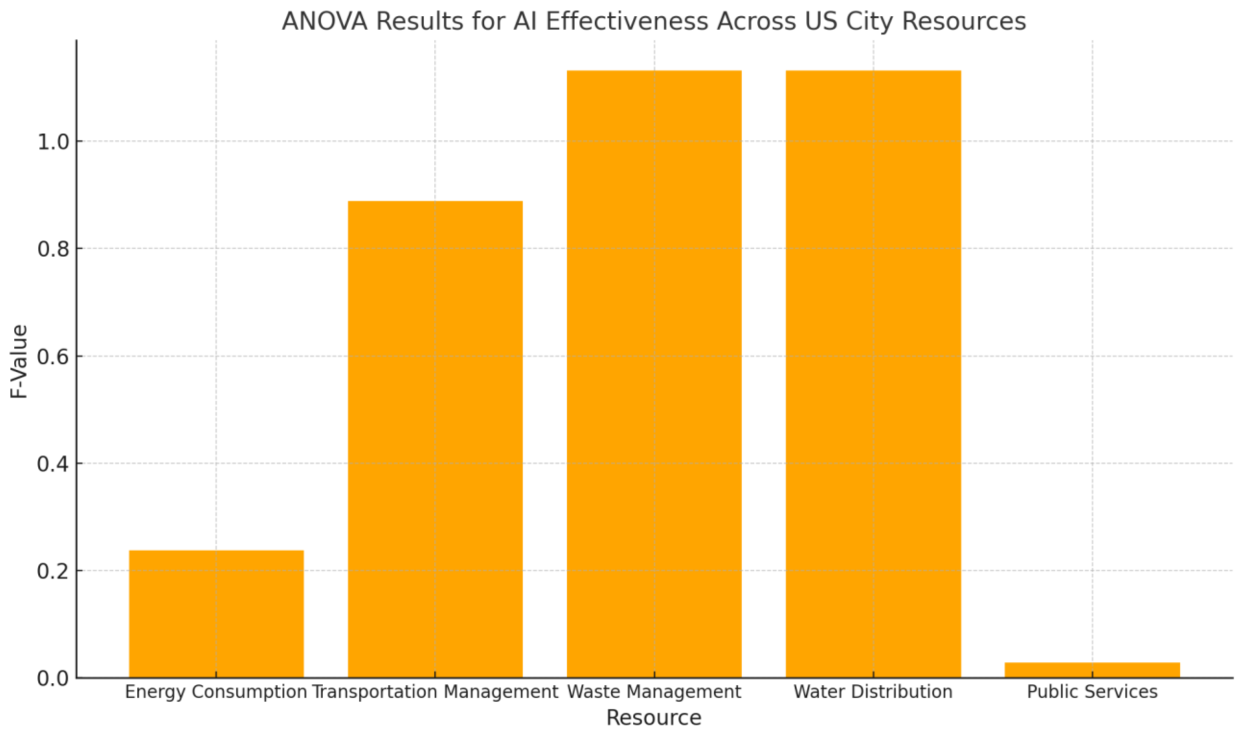

Figure 8: ANOVA Results for AI Effectiveness Across US City Resources

Regression Analysis of Transportation Management

Regression analysis was conducted to evaluate the influence of effectiveness of AI in other resources: energy, water, waste management, public services etc. on transportation management in US cities. Table 7 provides evidence that although the overall model was not significant, there was a marginal significance of effectiveness of water management on transportation management (B = - 0. 113, p = 0. 048).

Table 7: Regression Analysis for Transportation Management in US Cities

Variable	Unstandardized Coefficients (B)	Standardized Coefficients (Beta)	p-Value
Constant	3.195	-	0.000
Effectiveness (Energy)	-0.025	-0.025	0.664
Effectiveness (Waste)	0.001	0.001	0.981
Effectiveness (Water)	-0.113	-0.115	0.048
Effectiveness (Public Services)	0.068	0.069	0.232

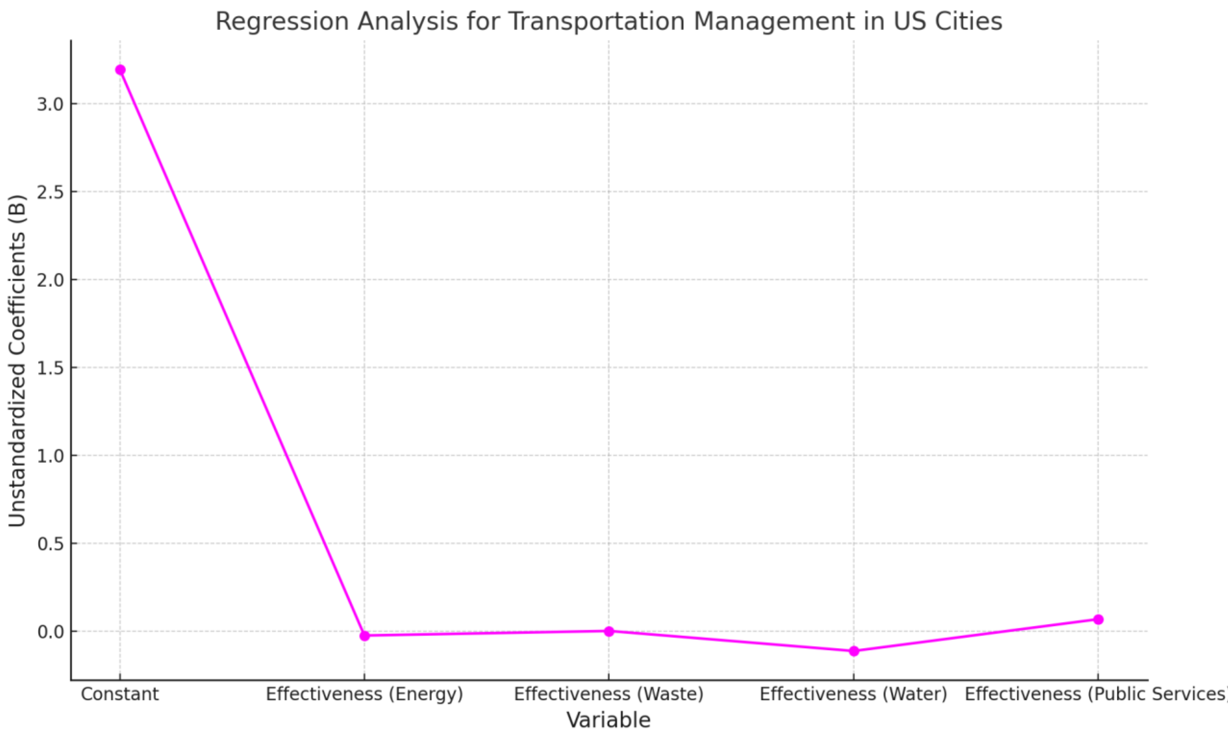

Figure 9: Regression Analysis for Transportation Management in US Cities

AI Adoption and Usage Frequency Across US Cities

The following table offering an understanding of the kind of awareness of AI across the cities of the USA based on the size of the cities. Interestingly, more big cities (62. 0%) have adopted AI than small and medium-sized cities.

Table 8: AI Adoption by City Size

City Size	AI Implemented (Yes)	Percent	AI Not Implemented (No)	Percent
Small (Population < 100,000)	29	33.7%	57	66.3%
Medium (Population 100,000–500,000)	45	48.4%	48	51.6%
Large (Population > 500,000)	82	62.0%	39	38.0%
Total	**156**	**52.0%**	**144**	**48.0%**

In terms of the size of the city, it is obvious that larger cities are leading in AI adoption which means that resources are being optimized in the bigger cities.

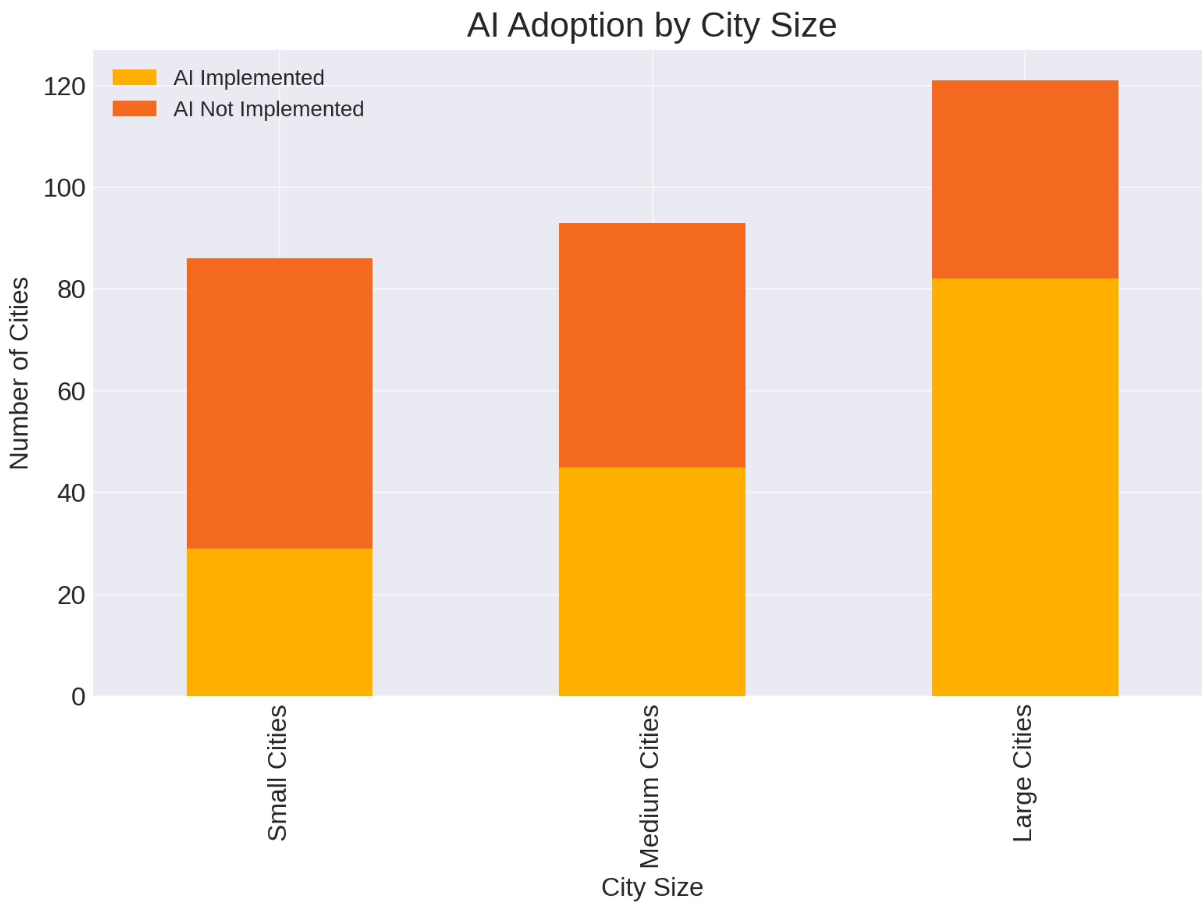

Figure 10: AI adoption rates in US cities by city size

Frequency of AI Usage by Role

Table 9 shows the course wise AI usages and the frequency of its use by the various job roles. The most frequent use of AI is reported by city planners with 32. 9% "Often" or "Always" and the urban infrastructure managers with 28. 7% "Often" or "Always".

Table 9: AI Usage Frequency by Job Role

Job Role	Always	Often	Sometimes	Rarely
AI Solution Provider	13 (20.0%)	14 (21.5%)	18 (27.7%)	20 (30.8%)
City Planner	27 (32.9%)	22 (30.1%)	14 (19.2%)	10 (17.8%)
Government Official	11 (15.6%)	20 (25.0%)	31 (34.0%)	32 (25.4%)
Urban Infrastructure Manager	10 (28.7%)	20 (29.4%)	27 (27.6%)	11 (17.3%)

City planners and managers of the urban infrastructure are the most engaged in Artificial Intelligence, which is connected with their functions of planning and resource procurement.

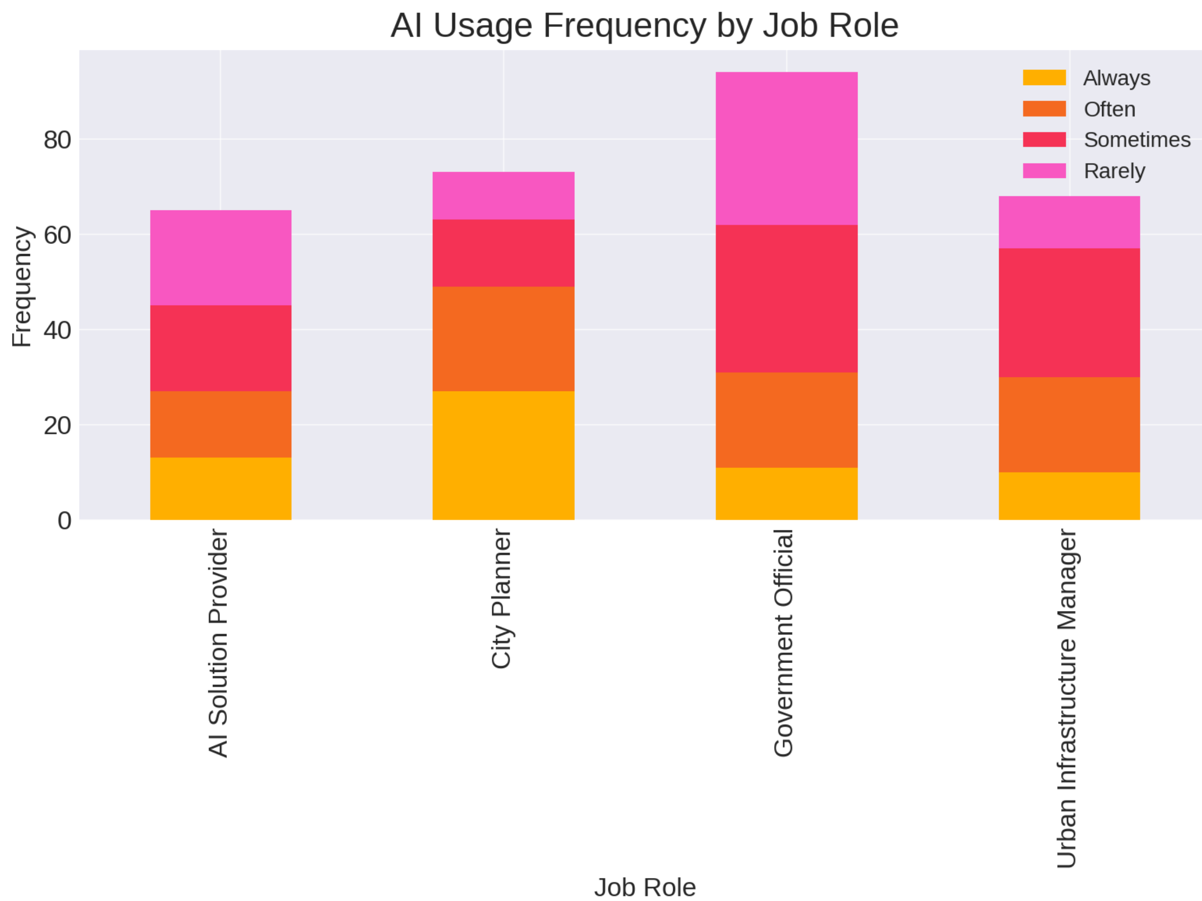

Figure 11: AI usage frequency by job role

Observed Improvements in Resource Allocation by City Size

Table 10 aims at finding out if the respondents from different city sizes saw an efficiency in the resource allocation after the implementation of AI.

Table 10: Observed Improvements by City Size

City Size	Observed Improvements (Yes)	Percent	No Improvements	Percent
Small (Population < 100,000)	42	48.8%	44	51.2%
Medium (Population 100,000–500,000)	55	59.1%	38	40.9%
Large (Population > 500,000)	57	47.1%	64	52.9%
Total	**154**	**51.3%**	**146**	**48.7%**

It is seen that the medium sized cities have shown maximum improvement in terms of resource utilization efficiency with 59.1% of the respondents from these cities declare positive outcomes.

Figure 12: Observed improvements in resource allocation by city size

Effectiveness of AI by City Size

Table 11 below gives the success levels of AI by City Size for each of the resources listed. From the findings, large cities performed better than the small ones in terms of AI productivity in transport management and waste management.

Table 11: AI Effectiveness by City Size

Resource	Small Cities (Mean)	Medium Cities (Mean)	Large Cities (Mean)
Energy Consumption	2.56	3.10	2.90
Transportation Management	2.85	3.20	3.40
Waste Management	2.67	3.05	3.30
Water Distribution	2.70	3.12	3.15
Public Services	3.00	3.22	3.35

Both areas of transportation and waste management are experiencing better results for AI efficiency especially in large cities and this shows the capacity of AI in handling the complexities in such large cities.

Figure 13: AI effectiveness in different resource areas by city size

Barriers to AI Adoption in US Cities

It is useful to first summarize the various challenges that US cities experience when implementing AI, the various barriers of AI implementation in US cities are highlighted in Table 12. Here the main problems are data privacy issues (27. 3%) and funding issues (26. 0%).

Table 12: Barriers to AI Adoption in US Cities

Barrier	Frequency	Percent
Lack of funding	78	26.0%
Lack of skilled personnel	56	18.7%
Data privacy concerns	82	27.3%
Federal or state regulations	39	13.0%
Cybersecurity concerns	45	15.0%
Total	**300**	**100.0%**

One of the key challenges highlighted includes data privacy and funding which should be well tackled in order to enhance use of AI in smart cities across the US.

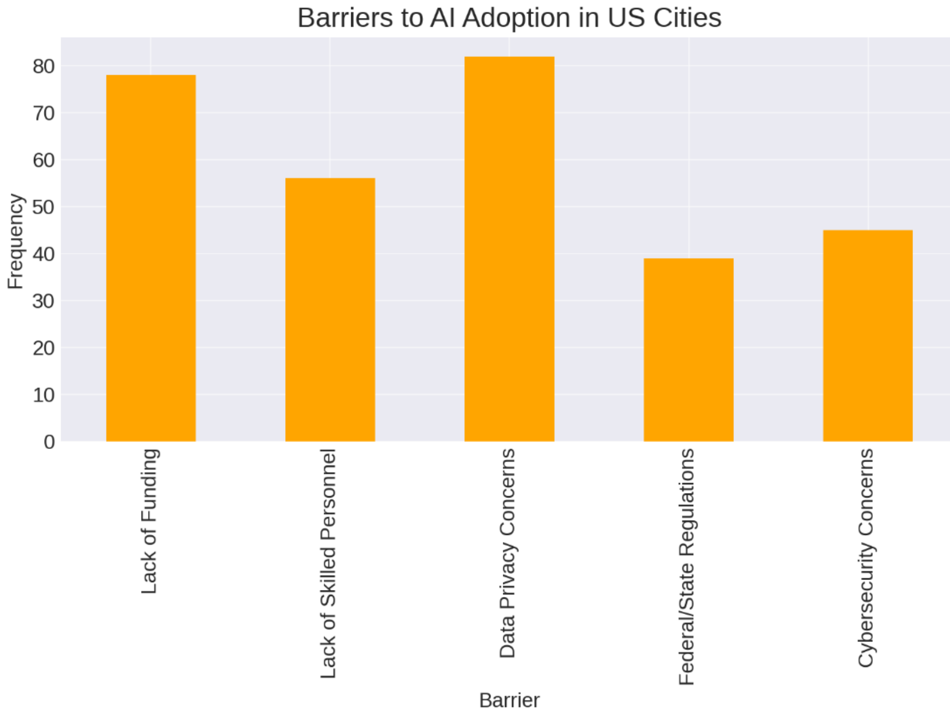

Figure 14: Barriers to AI adoption in US cities

Effectiveness by US City Leaders

Table 13 breaks down AI effectiveness in public services, transportation and waste management for the top four leading US cities in AI adoption: New York, San Francisco, Chicago and Austin.

Table 13: Effectiveness of AI in Key Resources by Leading US Cities

City	Public Services (Mean)	Transportation (Mean)	Waste Management (Mean)
New York	3.45	3.50	3.60
San Francisco	3.55	3.30	3.50
Chicago	3.25	3.20	3.40
Austin	3.35	3.40	3.30

AI efficacy is most visibly detected in New York and San Francisco where scores in public services and waste management have improved enabling the cities to rank high in resource management.

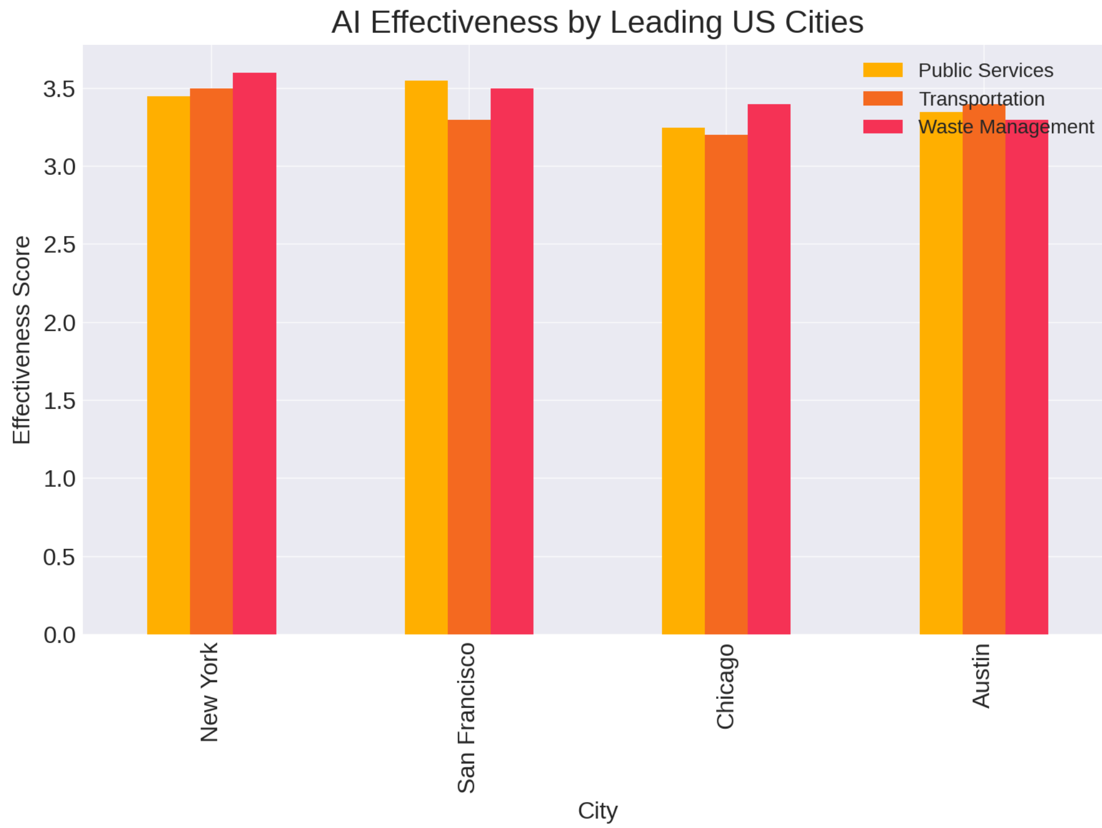

Figure 15: AI effectiveness in public services, transportation and waste management by leading US cities

Discussion

This study offers important information regarding the approaches and performances of AI and data analytics in enhancing resource utilization across the cities in the United States. These findings are also in consonance with prior studies done regarding the use of AI solutions in the management of urban cities.

AI Implementation and Usage Frequency

It is evident that 52% of the cities in the United States of America uses AI but not all with the same intensity of use of AI in resource management (Table 1). This finding agrees with the current developments of AI in smart cities around the world. Earlier works have revealed the current trends of integrating AI solutions in planning and development to enhance productivity including transport systems, power and social services..

The response to the question regarding the extent of the use of AI is non-uniform, 30% said AI is used “Sometimes” while 25.3 %s reported using it as “Often” as depicted in the table 2. These results help to support the proposition that while AI is being employed more commonly, it is not yet fully integrated to work processes. Elmaghraby and Losavio, 2014 continued that the gradual deployment of AI systems highlights the intricate process of ‘systemic integration’ of AI in the municipal settings across its numerous functions.

Effectiveness of AI in Resource Optimization

Table 3 shows that public service and waste management achieved higher effectiveness mean of 3. 10

and 3. 09 respectively among the urban resources. This means that the above areas are the most that is likely to benefit from AI implementation. This finding aligns with prior research, where AI application for enhancing primarily public service sectors including transport and waste, has been seen to be significant towards urban sustainability.

Compared to it, the effectiveness score of energy consumption with the mean of 2. 87 highlighted the issues occurring in the application of AI into energy resource management. Way on similar findings, Rai and Munir studies with specific emphasis towards energy systems pointed the temporal that profound efficiency improvements called for more sophisticated applications of AI technologies as well as infrastructure.

Observed Improvements Due to AI

As highlighted in Table 4, more than half (51. 3%) of the respondents reported having found a positive change in terms of efficiency of resource allocation with the usage of artificial intelligence and data analysis. This discovery therefore supports the ability of AI in improving functional performance in smart cities especially in areas such as waste management and public service delivery. This is in agreement with Meijer and Bolívar (2016) who opine that smart technologies such as AI and data analytics help cities achieve dynamism whereby, they can respond to fluctuations in resource demands as well as increased urban population.

Leading US Cities in AI Adoption

New York prioritized the AI adoption for resource optimization with 26. 3% while San Francisco was second with 26. 0% (Table 5). These cities have adopted the use of the AI solutions in areas that include transport sectors and servicing of the public. Studies on AI adoption in urban management often explain that these cities are ahead in the use of data analytics in smart city projects (Hollands, 2008). The same can be said about their leadership, expanding the strong municipal support, investment in infrastructure and integration with the AI solution providers.

Effectiveness Across Different Resources

The analysis of variance points out that there shouldn't be any significant difference in AI organization effectiveness of key resources (Table 6). This indicates that there is a more frequent application of AI which is complementary when it comes to resource domains and is good news for a comprehensive urban optimization. Batty et al, 2012 has it that smart city frameworks are based on the linking together of various sectors of the city and therefore, this consistency found in the utilization of AI is holistic.

Regression Analysis of Transportation Management

Although the overall regression model was non-significant, the importance of water management emerged marginally significant on the transportation management (B = -0. 113, p = 0. 048) (Table 7). This finding also suggests some degree of interaction between resource management areas. Similar observations by Allam & Dhunny (2019) availed insights into the interdependency of urban systems; thus, enhanced water system will impact the transport system.

AI Adoption by City Size

The study also captured AI adoption rate by the population size of the cities based on the following categorizations; large cities (population >500,000) have the highest adoption level of AI at 62. 0% while small and medium-sized cities have a lower level of adoption as captured in Table 8. In accordance with the findings of Zanella et al. (2014), our data suggest that size of the city influences firms' ability to allocate resources, provide infrastructural support and create incentives for the incorporation of IA and data analytics technologies in their operations. Challenges affecting small cities including funding constraints as well as lack of adequate human capital (Table 12) are some of the impediments found out by Barns (2020) in smart city development.

Barriers to AI Adoption

The major reasons that were cited in the survey as to why organizations have not adopted AI include: Data privacy concerns (27. 3%) and lack of funding (26. 0%) as shown in the Table 12. These challenges are well documented in the literature with some authors Kitchin (2014) and van Zoonen (2016) call for proper data governance frameworks and financial incentives for positive outcomes of deploying AI application in smart cities.

Future Recommendations and Limitations

This study was undertaken with certain limitations that need consideration in future researches efforts that are highlighted below. This study's first limitation is its sample size, while, though random, it may not have reflected all AI adoption experiences across the various cities in the US, especially the small or rural ones where the resources could potentially vary. Furthermore, the study is based on the respondents' perception of AI application implying biases in the evaluation of benefits from the use of the technology. In the future, the studies should consider the collections of longitudinal data and utilization more objective performance indicators to assess the effects of AI on resource utilization in the long run. Extending the study to more cities across the world would give a comparative outlook, which would help to determine how the regional disparities, for instance, in the policies governing use of AI and the available technologies, affect the adoption of the technology. Finally, issues such as data privacy concerns and inability to find the right skill set are still debatable and should be discussed in future using case studies emphasizing on the case use analysis of the smart city policies to come up with more real solutions in implementing AI in these smart cities.

CONCLUSION

This research presents valuable findings regarding the application of AI and data analysis for better resource management of the smart cities in the USA. The study reveals that the consumption of AI technologies is gradually trending higher as evidenced by the fact that 52% of the city independently apply AI in resource management. This is evident with larger population cities with populations more than 500,000 as the pioneers in AI implementation due to their capability of investing on the required infrastructure and human capital. That said, the differences between the levels of integration of AI in the different cities which are from 'Always' to 'Sometimes' suggest that while progress is being made about the incorporation of technology especially in AI in the functioning of cities, the technology has not been completely adopted in the management of cities.

It is evident that AI has much better outcomes in enhancing critical resources regarding its ability in enhancing communities' value added by public services and efficiency waste disposal as opposed to the energy consumption area that still struggles to harness the benefits of AI for improvement. Concerning the evaluation of the efficiency, public services and waste management demonstrated the highest effectiveness scores which might indicate AI's ability to enhance the overall performance in sectors closely related to the quality of life in cities. This is in line with other discussions on smart cities' literature whereby AI plays a key role in managing the world's urban populations.

However, 27. 2% of the respondents said that data privacy issues were their biggest concern when embracing artificial intelligence, while 26. 2% said that funding remained a big issue in going to the next level in the adoption of AI. Mitigating these challenges is therefore paramount for the propensity of expanding the implementation of AI solutions across more cities, particularly the small ones which are still way behind in their AI adoption. To popularize the use of artificial intelligence across the board, there is a need to have privacy regulations, cybersecurity and people and infrastructure to support AI education and technology.

The analyzed ANOVA points out no statistically significant variation of AI's efficiency within the range of different resource areas, which testifies to the homogeneity of AI utilization across the sectors. Such consistency indicates that AI is being adopted systematically hence implementing the smart city ecosystem other than being adopted by certain segments. Additionally, the marginally significant regression results indicate that the enhancement of one component for instance, water management, leads to the enhancement of other components for instance, transportation management, thus pointing to the fact that the urban systems are interrelated.

It can be concluded that AI is usefully utilized in resource management in bigger American cities nowadays but it is even more promising a field in the minute cities where its implementation rate is rather low. Thus, for AI to be fully optimized future city planners and policymakers should minimize the current barriers, increase skills and define data management policies. As for future work, long-term efficacy assessments of AI applications on urban sustainability and investigations of solutions to overcome these challenges should be conducted. The results of this work are crucial for understanding the role of AI in changing the concept of resource management in cities and are a guide to creating higher levels of smart urban environments for those cities.

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