Applications of Data Science and Artificial Intelligence in Public Policy

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The government of India is the final authority for country-wide policy making and policy implementation in the country. Recent times have witnessed increasing use of data-driven approaches in policy and decision making. This is true for public policy formulation as well. This paper is an effort to highlight how data science and artificial intelligence have the potential to revolutionize the field of public policy in India. The paper discusses some such applications and lists down the likely challenges. An extensive review of the research activities in this field has been undertaken. Cases of data science and artificial intelligence reviewed in this paper span over various sectors of public policy such as- policy making process, health, education, environment, agriculture, economy, and security. This paper, thus, aims to facilitate collaboration in the fields of public policy and data technology, in order to enable higher levels of public service in India.

Keywords: Data Science, Artificial Intelligence (AI), Machine Learning, Public Policy

1. Introduction

Data Science (DS) is the field that makes use of mathematics, discipline understanding and computer science to explore and analyze data to find answers to questions that humans would take ages to answer. Artificial Intelligence (AI) can be defined as the ability of machines to think or emulate the intelligence of human beings. Patrick and Williams (2020) have described this in an illustrative manner that calculators are not AI as they require a human to "tell' them about operations to perform whereas, an image recognition software is an AI as it makes intelligent decisions on its own. Both data science and artificial intelligence (collectively, 'data technologies') make use of data in huge quantities. The development of storage and computing capabilities has driven the advancement of these technologies. They have, in return, substantiated human lives by increasing productivity and speeding up the tasks and decision making in numerous fields.

Formulating public policies is an essential part of governance. It is the primary function of a legislature. Policy of an organization defines the actions it has taken or proposes to take. Sapru (2012) defines public policy as "what a govt chooses as a guidance for action". He further establishes its connection with 'decision making'. Policy making involves taking some decisions, but a decision does not necessarily

form a policy. In most polities, formulation of a public policy is undertaken by the government, though it may be delegated to public/ private research bodies. In India, the legislative body in charge of framing the policy often invites recommendations/ draft policies from committees, commissions or policy think tanks. The final policy is then ratified by the Parliament of India.

Digitization of government services in India has led to the availability of huge amounts of citizen data with the government. This data holds a lot of potential if fed into the policy making process. Data science and big data analytics can provide the policymakers with useful insights regarding resource optimization and category prioritization which can ensure more efficient and cost-effective policies. Artificial intelligence and machine learning models can mimic the actual implementation and provide estimates of results and metrics of the policies, ensuring more effective policy deployment.

This paper is a review of the body of literature and research available on this topic. The qualitative and quantitative data is obtained from several research papers of various journals and websites of ministries of the Government of India. Some use-cases of countries other than India have been included to facilitate their scalability in the Indian context.

This research paper distinguishes itself from the existing work in this field in the following three ways: one, emphasis has been laid on catering to the process of public policy in the country of India; two, the paper tries to cover various sectors of public policy extensively; and three, recent developments in the Indian policy context related to these two technologies have been included. This paper is an attempt to ensure inclusivity and comprehensibility about the topic, however, in a rapidly developing field such as this, exhaustiveness cannot be definite. Nevertheless, this work shall provide a useful overview to the policy makers and researchers interested in this arena.

2. Applications in the Public Policy Making Process

The raw material for implementing data science and artificial intelligence models- data, is abundantly available with the governments because of the digitization of various services. Governments can make use of this enormous data by feeding it into the policy research. This would lead to better and effective policies. Data science and big data analytics can help the policy makers to support their empirical arguments with data insights. Further, artificial intelligence algorithms can be deployed to make models to predict the results/ metrics even before the actual implementation.

Data technologies can also be used in the appraisal policies of civil servants of the country. This could hugely impact the public policy space, given the civil servants' (especially the Indian Administrative Services') role in the formulation and implementation of these policies. Use of data and metrics in promotion and work allocation would ensure more efficiency and accountability. Vaishnav (2016) terms this as 'cleaning rust from the frame' (a reference to then British Prime Minister David Lloyd George's mentioning of Indian Civil Services as 'steel frame' of the government).

However, there exist a few concerns associated with the applications of Data Science and Artificial Intelligence models for formulating public policies. Unauthorised usage of citizen data can lead to encroachment of privacy rights of the individuals. Real life biases by data handlers or data administrators could potentially

get transferred to these models. This would make these models (and subsequently, the results) biased and discriminatory. Chances of cyber-attacks or hacking attempts need to be considered too, as this can severely threaten the citizen privacy and integrity of data model.

To allay similar concerns in the big private corporations, Thuraisingham (2020) advised setting up the offices of Chief AI Officer (CAIO) and Chief Data Officer (CDO). Similar approach can be adopted by the governments too. Further, cyber security protocols and removal of identifiable information from the citizen data must be given adequate emphasis, more so as the Personal Data Protection Bill 2019 is yet to be ratified by the Parliament of India (as of June 2022).

3. Applications in Public Health Policies

The human body produces a lot of data points every day. These are in the form of blood pressure levels, sugar levels, temperature, lipid concentration in blood, etc. This huge amount of data has remained largely untapped until the development of the fields of data science and artificial intelligence. Recent data technologies hold the potential to revolutionise the health sector.

Data scientists and researchers have been able to deploy big data analytics and machine learning models to detect various chronic diseases in humans, well in advance. In one such research, Junaid and Kumar (2020) researched the application of data science algorithms like Naïve Bayes and Support Vector Machine to predict chances of heart diseases for a person in advance, by factoring in various lifestyle and genetic attributes. Similar research can help the government formulate policies aimed to reduce mortality due to various chronic diseases.

A study by Pandey et al. (2018) has put forward that majority of the healthcare spending in India is of 'out-of-pocket' nature i.e., healthcare bills are paid by the households from their earnings rather than public spending by government. This is because of the sub-par and limited public health infrastructure. Newer data technologies provide promising solutions that can make this sector cost-effective and inclusive. Encouraging the use of big data analytics for personalized healthcare treatment could result in cost cuts and lesser pressure on the limited health equipment and resources. Personalized treatments are expected to be more efficient and effective too. Kumar (2016) found them to be instrumental in reducing the readmission rates considerably. Further, patients in remote areas can be treated without a physical presence, if the virtual presence and access to patient data are ensured.

Latif et al. (2020) described how data science algorithms can be used in 'patient prioritisation' by estimating the mortality risks after considering various factors like age, comorbidities, gender, etc. This would enable health policymakers to make well-informed decisions and would ensure adequate emphasis towards the most vulnerable age groups and communities.

The use- cases of data science and artificial intelligence in health sector have become even more significant, given that the health ministry of India approved Health Data Management Policy in December 2020 under the National Digital Health Mission. The policy (National Digital Health Mission [NDHM], 2021) proposes to maintain digital health records of citizens, health officials, and health facilities by issuing them a 'Health ID'. This will ensure availability of ample amount of data with the government, which will enable better applicability of the data technologies.

COVID-19 pandemic (2020-), which wreaked havoc in the world, prompted numerous researchers to find applications of these technologies in health sector during pandemics. Machine learning models can help the government to make intelligent decisions to battle epidemics and pandemics. Predictive models can help to evaluate the number of days of lockdown required to control the spread of the disease while minimising its effect on the economy of the country. Patwa et al. (2020) describe how machine learning algorithms can be used by government agencies to keep a check on fake news, misinformation, and rumours, which have the potential to adversely affect public health, especially in pandemics like COVID-19 (which the researchers have termed as 'infodemic'). Data science and artificial intelligence algorithms can be deployed to forecast demand for medicines or essential equipments in different parts of the country during a pandemic. This would help to effectively redistribute the resources and will lead to lower fatalities. Qin et al. (2020) used search engine keywords index in China for words like 'dry cough', 'fever' etc. to predict the number of new cases of COVID-19 in an area during the pandemic in 2020. These technologies have their applications in the field of drug and vaccine discovery as well. The scientists have utilized machine learning models to funnel out the most effective vaccine candidates for COVID-19. Arshadi et al. (2020) describe how such models can predict potential inhibitor candidates by identifying patterns in unstructured data, given a target biomolecule.

These technologies, while having numerous applications, pose some challenges too. These would need to be addressed to enable better implementation. Incorrect or biased results can cause a lot of damage as the resulting inaccuracy may get passed on to the final policy measures, threatening the lives of many. The use of data science in fields like genome mapping may expose society to 'scientific racism' (Carter, 2007) by deepening the fault lines of 'racial purity'. Data privacy concerns need to be considered too. Worth mentioning are provisions in the Health Data Management Policy of the Government of India, which lay down a clear framework to ensure high data security standards. Also, proper implementation of such guidelines would be the key in such cases.

4. Applications in Education Policies

Data technologies offer wide range of applications in the online education and e-learning sector. Several researchers (like Mishra et al., 2020) have demonstrated how the COVID-19 pandemic and lockdowns around the world in 2020 led to a sharp rise in acceptance of online courses as an essential part of learning. This has contributed to an increase in availability of learners' data and thus, the use of data science and artificial intelligence in the education sector has become more plausible than ever.

Klašnja-Milićević et al. (2017) establish how online learning could be made more interactive and efficient through the use of AI. Use of AI chat-bots can help to reduce the response time for learners' questions and doubts. Further, different types of learners' interaction with the online interface can be recorded (like number of times the lesson is paused, time taken to complete a lesson, and most importantly, test scores). This data can then be subjected to analytics to gain insights about learner's way of learning. The shortcomings and areas that require more focus can be deliberated to the learner. This method of 'personalized education' would increase the effectiveness of the learning.

Artificial intelligence provides a means to automate some repetitive and redundant tasks for the teachers/ educators in the education sector. Jaakkola et al. (2020) in their research paper cited a study that showed that fifty one percent of the teachers' workload is not related to direct teacher- student interaction. It can be reduced by half with the use of technology and the saved time can be allocated to activities that augment students' learning. For example, AI powered automation can be used to grade tests/ quizzes and give valuable feedback, a task on which teachers spend 6.5 hours per week on an average, according to the same study.

Further, a study (National Institute for Transforming India [NITI Aayog], 2018, p. 35-38) mentions how AI and data analytics can be used to reduce the 'drop-out' rates in India. As per the figures mentioned, as high as one-third of the enrolled children in India drop out before finishing Class 8. Data technologies could be used to predict in advance, the probable dropouts in a school by analyzing various factors like gender, attendance data, socio-economic background, exam scores etc. This can enable pro-active action like counselling to prevent the drop out.

As Artificial Intelligence is expected to play a major role in all aspects of life in the coming times, researchers have demonstrated the need to include AI and data technologies in the school curriculum. Kandlhofer et al. (2016) devised an AI education framework with modules for all age groups ranging from children in Kindergarten to those in University. This is in line with Government of India's National Education Policy 2020 in which the government named 'coding' as a '21st Century skill' and included it in the curriculum from as early as Class 6th onwards. Familiarizing children about coding skills at an early age will ensure a greater number of students taking AI and DS as career prospects in future, thus, leading to greater advancement in these fields.

Government can make use of Natural Language Processing (NLP, a sub-field of AI) to translate vast amount of cultural literature, government reports and scholarly work in a very short amount of time and at a low cost. A national repository or an online library could then be created of the literature in various languages of India. This will help to promote the use of local languages amongst scholars, teachers and students. NLP can also be used to create automated content like questions, chapter summaries.

Though the applications of these technologies in the field of education are numerous, the effective implementation in India can be achieved only once the associated concerns are addressed. First, the use of these technologies would require a significant amount of financial investment by the knowledge providers or government. Second, the process of data collection may be subjected to ethical and privacy related apprehensions. Third, there is a need to equip teachers with AI skills to make them able to use AI powered education systems. Fourth, use of data technologies may reduce human-to-human interaction.

5. Applications in Environmental Policies

Use of data technologies can help people better understand the environment they live in. Analysis of data of routine aspects of life in relation with carbon emissions can help scientists to better understand the impact of anthropogenic activities on climate change. This would enable people to discover and adopt sustainable alternatives. Machine learning and data science can be applied to remote sensing data to predict various geographical phenomenon like air pollution levels, rainfall pattern etc. Satellite data can be used to measure different parameters on Earth like sea level,

ground water level, chemical composition of atmosphere, size of glaciers and ice caps. The measured data can be fed to data models to gain useful insights about environment. Big data analytics can be leveraged for better resource allocation and resource optimization via forecasting of demand and supply. This would lead to usage of fewer resources and thus, lesser environmental degradation. Khareghani (2020) showed that artificial intelligence can help in better acceptability of renewables. Generally, grids that have renewables as their source, make use of 'reserve power' that is very often provided by non-renewables. This is done to counter the uncertainty in demand of power. AI and machine learning models could be deployed to forecast the demand of power in advance. This will enable the grid operators to do away with the use of non-renewables.

Complacency and denial by some are the major causes behind environmental degradation and global warming. Climate change deniers undermine scientific facts because of the belief that the consequences are not immediate. Luccioni et al. (2021) created a personalized climate impact visualiser tool using artificial intelligence to make people visualise the devastating effects of climate change and global warming. Machine learning models can thus, be created to forecast the future environmental situation based on data on present rate of climate change. This would also enable policy makers to make better environmental protection laws and policies.

Environmental degradation and global warming could exacerbate frequency of the occurrence of extreme weather events like floods and droughts. Machine learning models can use the satellite and daily weather data to predict occurrences of such events in advance which would prevent the loss of property and lives. For instance, Kawasaki et al. (2017) created 'Data Integration and Analysis System' for disaster risk management in Japan.

Researchers and policy makers have flagged some of the limitations of the data technologies in their applications to this sector. Schmidt (2020) describes how AI predictions are prone to inaccuracies due to factors like poor data qualities and how these may cause more harm than good, if not addressed. Also, Earth being an active system, the factors like temperature and pressure are often influenced by localised variabilities and anomalies. Apart from the data privacy and proneness to cyber-attacks, machine learning and big data analytics models are themselves quite energy intensive. High end computations heat up the server and hardware severely and huge amounts of water is used to cool them off. Luccioni et al. (2020) created a 'Machine Learning Emissions calculator' to quantify the carbon footprint of machine learning models. This highlights the need for making data technologies less energy intensive and more sustainable.

6. Applications in Agriculture Policies

The agriculture and allied sectors contribute 17.3 percent of the Gross Value Added (GVA) of India (2016-17 data) and employ about fifty percent of the total workforce (Central Statistics Office [CSO], 2019). Agriculture sector in India faces many problems today such as low productivity, land degradation, excessive use of chemical fertilizers, over reliance on monsoons, lack of crop diversification, lack of adequate logistic and marketing support systems etc. Many researchers have applied data technologies to provide viable solutions to some of these problems.

Indian agriculture is overly dependent on monsoons (seasonal rains). This results in a lot of uncertainty in the production in the years of bad monsoon. As discussed in the last section, data science and big data analytics can help in prediction of climate and weather phenomenon in advance and thus, can help in reduction of farming sector uncertainty in India. Further, agriculture sector is the one that is most affected by the climate change induced adverse events like floods, droughts, etc. Usage of these technologies in countering global warming will benefit farmers across the world. Lyubchich et al. (2019) formulated machine learning model to provide risk assessment in the agricultural insurance sector due to climate change. If adopted by the insurance providers, it will enable them to provide better insurance packages to the farmers.

Agriculture sector in India suffers from uncertainty in the price of produced commodities too, especially in the horticulture sector. This is due to the fluctuations in the supply and demand of those commodities. Big Data Analytics can be applied in this case to help the farmers gain understanding about the level of demand of their product across their region or other regions. This will enable the farmers to get better price quote for their produce. Mooney (2018) reported that big-tech companies like Microsoft and Google have been deploying their big data capabilities to disseminate market information to farmers.

Growing population demands more food grains. This creates the need to bring more area under agriculture, which leads to deforestation. Scientists have developed AI-based solutions to solve this problem via 'environmentally conscious agriculture'. Sydney (2020) mentions about an Israel based company that developed AI algorithm to optimise the amount of sunlight, water and nutrients to enable plants to grow in an urban setup without open land.

NITI Aayog's Discussion Paper advocates the use of artificial intelligence for 'precision farming' (NITI Aayog, 2018, p. 34). This model of farming involves optimal usage of farm inputs like pesticides, fertilizers and water for farming. IBM in partnership with NITI Aayog developed an AI model for precision farming in India. Adoption of such methods would reduce farmers' expenditure while being environment friendly.

AI could be used to help the farmers to increase the crop yield in many ways. Vohra et al. (2019) formulated a system using AI that could let the farmer know if the crop is about to get rotten, well in advance. This could prevent ruination of crops and wastage of the produce. Similarly, Al-bayati and Ustundag (2020) established usage of AI in detecting plant diseases like Apple Leaf disease. AI algorithms can also be developed to detect the presence of intruders or animals in the field which can potentially harm the crop.

Developing countries like India have limited financial resources to be spent on agriculture sector. Data science and artificial intelligence today are investment intensive technologies. These technologies will require farmers to have access to smartphones/computer and internet access. This may lead to increase in the farmers' expenditure as well. Thus, there is a need to develop more affordable solutions to be applied to a country like India. Smith (2020) outlined other potential negative consequences of usage of these technologies in the farming sector. According to him, leaving decision making in the hands of computers may lead to higher risks of errors or wrong decisions as compared to human intelligence and expertise. Further, replacing manual labour with machines will lead to unemployment among the unskilled labourers.

7. Applications in Economic Policies

Various data science and artificial intelligence models have been developed by researchers that can be either used to solve various economic problems or can augment the policy making in this sector. The ability of the machine learning models to forecast and predict, is the most important facet of the technologies that is leveraged in this sector.

Data science and machine learning models can be deployed by the government and Reserve Bank of India (RBI) to forecast various macro-economic indicators like unemployment rate, GDP (Gross Domestic Product) growth rate, inflation rate, Non-performing Assets (NPA) ratio with the banks etc., with better precision. These estimates can then be used to take better policy decisions in the economics of the country. Further, Krukovets (2020) described how Natural Language Processing (NLP) can be used to extract public sentiment information from various text sources like news articles, social media; and how this can lead to better and more precise forecasts.

Skirka et al. (2020) applied Machine Learning algorithms like decision tree and used statistical techniques like confusion matrix to quantify 'level of trust', people have in European Central Bank. Similar models can be applied to the banks in India. This would help the government to gauge the level of services banks are providing to the people.

Another widely known use-case of data technology is demand and supply forecasting. Government could make use of such forecasting models to predict number of people who want to avail a particular service, say application for a new bank account. This can enable better resource mobilization for better service delivery.

Thus, the use of DS and AI, if encouraged by the Government can help reap better policy results. Last few years have seen governments across the world adopting these technologies in the economic policy sector. For example, Union Finance Ministry of Government of India launched Project Insight in 2017 to detect tax-evaders by monitoring high value transactions via the use of big data analytics. Under this project, government plans to sense discrepancies between spending pattern and income declaration from the open data of users on their social media accounts.

8. Applications in Internal Security Sector

Before the advent of artificial intelligence systems, security personnel had to manually look out for potentially harmful human actions in video footage. However, image recognition algorithms have reduced dependence on manpower for this activity. This has led to better efficiency and accuracy and has enabled real time threat detection. For instance, police in the Indian city of Lucknow launched a project (Rashid, 2021) to install AI-enabled cameras at the 'harassment hotspots', which will detect changes in facial expression of women (to one of distress or extreme anxiety) and will alert the nearest police station on potential case of sexual harassment. NITI Aayog Discussion paper on Artificial Intelligence (NITI Aayog, 2018, p. 40) mentions the application of similar technology in crowd management. It gives example of the 'Kumbh Mela Experiment', in which authorities used AI solutions to predict possibility of a stampede after analyzing crowd behavior from live video data.

Use of data technologies at borders can act as a game-changer in the field of border management. Deploying AI systems has many advantages over using traditional border security apparatus. They can help reduce the human errors at the borders. Unmanned vehicles can be used to improve mobility in difficult terrain and can help save precious human lives. AI-enabled surveillance systems would enable 24x7 guarding of the borders. One such initiative was launched by Ministry of Home Affairs of Government of India in 2019- called 'Comprehensive Integrated Border Management System' (Press Information Bureau [PIB], 2019). It envisaged data gathering via satellite mapping, surveillance cameras, infrared sensors. The data would then be used to do a comprehensive analysis to gather useful insights.

However, these technologies have their own challenges and concerns like huge investment costs, lack of trained personnel, proneness to enemy's hacking attempts, and machine errors; which need to be addressed for more efficient deployment.

9. Applications in Infrastructure Sector

Infrastructure is an important sector for developing countries like India as it helps in faster economic growth and enhanced standard of living. Use of data technologies can help in building 'smart' infrastructure. Government of India launched National Smart Cities Mission in 2015 to transform one hundred selected cities into 'Smart Cities' (Smart Cities, 2021). A 'Smart city' is a city which is live-able, sustainable and has a thriving economy, and this is achieved via use of technology.

One of the major problems faced by city dwellers is of poor traffic management. AI systems would help overcome this. Effective traffic management will enhance road experience and will help to reduce power consumption in automobiles, thereby, reducing air pollution. Gandhi et al. (2020) made use of image processing and artificial intelligence to calculate traffic density from live camera footage and accordingly enable switching the traffic lights to green or red. Franklin and Mohana (2020) described an AI and computer vision model to detect traffic signal violations.

Machine learning models can be used to optimise the land use pattern in order to accommodate ever growing number of people in the cities. Data from mapping apps (like Google Maps) can be used to design efficient and cost-effective road network to connect two or more places with one another.

DS and AI models can be deployed in the smart cities to ensure optimal usage of natural resources like water, energy; to ensure public safety; and better service delivery by government.

10. Conclusion/ Managerial Implications

Data technologies have found the usage in public policies of various sectors. Data science and big data analytics would help the policymakers to support their empirical arguments with data insights. Artificial intelligence algorithms can be deployed to make models to predict the metrics of the policy even before the actual implementation. These technologies can help the government both in policy formulation and policy implementation processes. They provide efficient and effective health solutions too. Data science and artificial intelligence have numerous applications in the environment and agriculture policy making. Further, they have the potential to make education and learning more productive for the students. These technologies also provide viable solutions to problems related to the economy, internal security and infrastructure. However, effective implementation can be ensured only if the related concerns are allayed.

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