SHIV NADAR
INSTITUTION OF EMINENCE DEEMED TO BE
UNIVERSITY
DELHI NCR

SUSTAINABILITY INITIATIVES

IMPACT STORY 5

DATA-DRIVEN INSIGHTS USING MATHEMATICAL TOOLS CAN INFORM PUBLIC HEALTH STRATEGIES.

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Overview

Teaching and Research at the university can be powerful drivers to create a ripple effect of impact stories. This knowledge and ideas - when they leap from university laboratories and lecture rooms into society through partnerships, begin to make an impact.

At Shiv Nadar University, we bring you some of these impact stories through this series. The stories feature our faculty, their research, and their students creating a difference and contributing to UN Sustainable Development Goals (SDGs).

In this story, we bring you Dr. Samit Bhattacharyya's work from the Department of Mathematics to show how mathematical tools have a transformative potential to create insightful research and address real-world challenges.

Samit Bhattacharyya

Associate Professor,
Department of Mathematics
Shiv Nadar University, Delhi NCR

In conversation with Dr. Samit Bhattachrya

Dr. Samit Bhattacharyya is an Associate Professor at the Department of Mathematics.

Dr. Bhattacharyya's research interests lie in the interface of Mathematics, Biology, and Statistics. Using mathematical tools such as nonlinear dynamics, game theory, and optimization, he tries to understand the complexities of ecology at the population and individual levels and the evolution of infectious diseases of humans and wildlife, including childhood infections and emerging infectious diseases. His work addresses the spatiotemporal dynamics of infectious disease, the ecology of disease and management, and the impact of social norms and human behavior in disease and policymaking.

The field of mathematics is somewhat skewed. Your research, however, has shed interesting light on how Mathematics tools can be powerful in understanding the emerging field of infectious diseases. What has motivated your research?

My motivation for research stems from the transformative potential of mathematical modeling to tackle certain pressing real-world challenges, such as health, climate change, and the environment. By focusing on areas such as antibiotic drug resistance, bed net usage in malaria, treatment-seeking behavior in tuberculosis, the influence of social media on disease transmission, and understanding the impact of pollution on health, my laboratory aims to provide **data-driven insights that inform public health strategies.** These models help predict disease dynamics, optimize interventions, and combat misinformation, contributing to global health and sustainability.

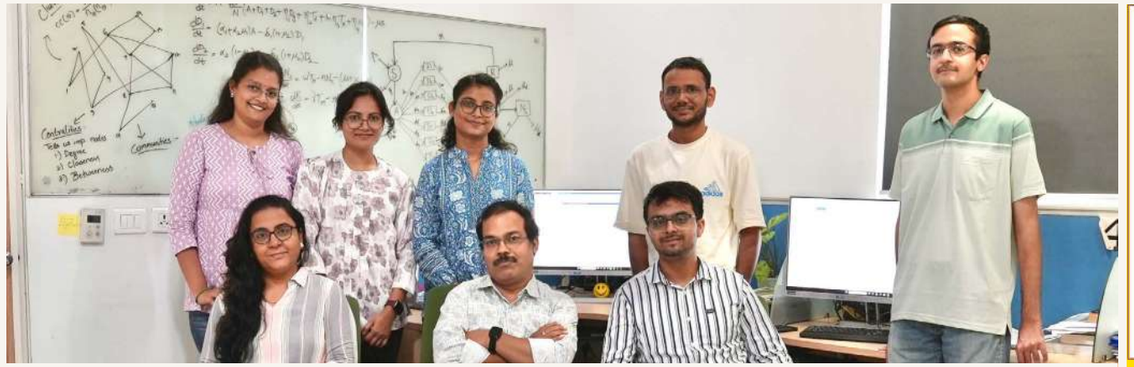
You head the Disease Modelling Laboratory at the University. When was it set up? Please share some key research projects hosted in the lab.

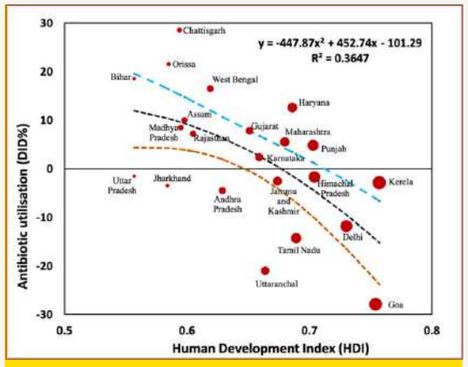
The Disease Modelling Laboratory was set up at the university in late 2015. The inspiration to establish this lab was drawn from my time at the Center for Infectious Disease Dynamics (CIDD) at Penn State University, where I spent over 3.5 years conducting postdoctoral research. The lab has been instrumental in advancing research on various critical aspects.

Past projects include studying antibiotic drug resistance as a complex system influenced by socioeconomic factors. Optimizing budget allocation for vaccination campaigns using game dynamics.

Currently, we are engaged in several significant projects, including the Global Technical Strategy for malaria elimination in Sub-Saharan Africa, integrating socio-demographic and behavioral factors.

We are also developing models to explore some of the deeper questions, such as how treatment-seeking behavior impacts TB burden, especially in low and lower-middle-income countries; how personal beliefs affect vaccinations in populations; and how pollution levels in India for PM10 and PM2.5 might change in the future. Our larger aim through these projects is to enhance and inform public health strategies and sustainability.





People left to right: Manalipadam Lakshmi, Monica Dhyani, Preeti Saini, Saif Abbas, Pranav Verma
Left to right (sitting): Laxmi, Samit Bhattacharyya, Viney Kumar

UN Sustainable Development Goals is one of the critical frameworks for checking global progress towards sustainability. How does your work contribute to some of these SDG Goals, and what are some key elements of your research in recent times?

Our vision for a sustainable future necessitates addressing critical health challenges and environmental impacts through innovative research. My work contributes to several UN Sustainable Development Goals (SDGs) by utilizing mathematical modeling to enhance public health outcomes and environmental sustainability. My research on antibiotic drug resistance and ITN usage in malaria provides crucial insights for disease prevention and treatment and contributes to Sustainable Development Goal 3 - Good Health and Well-being.

My work on addressing human behavioral impacts on TB and the role of social media in vaccination aligns with SDG 4 - Quality Education and 10 - Reduced Inequalities by promoting informed health practices and equitable access to accurate health information. My project on pollution control modeling addresses SDG 13 - Climate Action, addressing how to mitigate environmental factors that exacerbate disease spread.

We are also working on developing predictive models for disease outbreaks, optimizing health intervention strategies, and analyzing the impact of digital misinformation on public health behaviors. These efforts are essential for forming data-driven policies and interventions that advance global health and sustainability.

By focusing on areas such as antibiotic drug resistance, bed net usage in malaria, treatment-seeking behavior in tuberculosis, the influence of social media on disease transmission, and understanding the impact of pollution on health, my laboratory aims to provide data-driven insights that can inform public health strategies.

How have you been able to connect and include sustainability in your teaching?

I integrate sustainability into my teaching by demonstrating how mathematical concepts can address real-world environmental and health challenges. After joining Shiv Nadar, I have developed undergraduate and graduate courses such as Mathematical Modelling, Biomathematics, and Evolutionary Game theory and applications, Probabilistic models, Statistical inference, and others.

In all such courses, we have introduced models of disease spread and pollution dynamics to illustrate how mathematical and statistical equations can be utilized to project and predict the dynamics of biological systems. In the optimization course, we focused on sustainable resource allocation and efficient intervention strategies. Through game theory and simulation studies, we demonstrated how cooperative strategies can lead to better public health and environmental outcomes. Nonlinear Dynamics courses include studies on the complex interactions between human behaviour and ecosystem health. These approaches not only equip students with robust mathematical skills but also instill confidence in how to use these tools to advance sustainability.

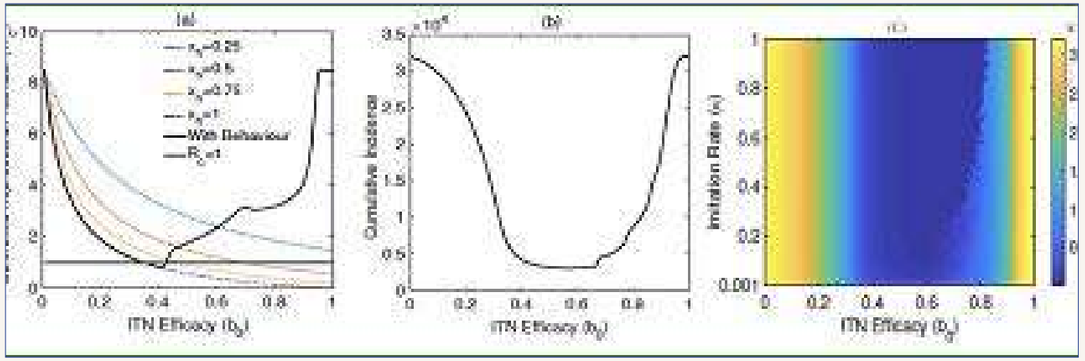
Your research students have done some interesting work. Please share examples or highlights of your students' key research projects.

Here, I would like to highlight a few of some very interesting research work that my students have done.

Strategic Modelling for Efficient Use of Domestic and Donor Funds to Combat Malaria in Sub-Saharan Africa.

This research focuses on human intervention in Malaria elimination efforts in Sub-Saharan Africa (SSA). It highlights that increasing the efficacy of insecticide-treated nets (ITNs) may not be enough to eradicate malaria in many SSA countries.

Instead, the study suggests that socioeconomic subsidies are necessary to increase voluntary ITN usage. As the next step, the research is developing models to design an optimal strategy for how domestic and donor funding can be utilized effectively to achieve the earliest possible elimination of malaria in SSA countries.

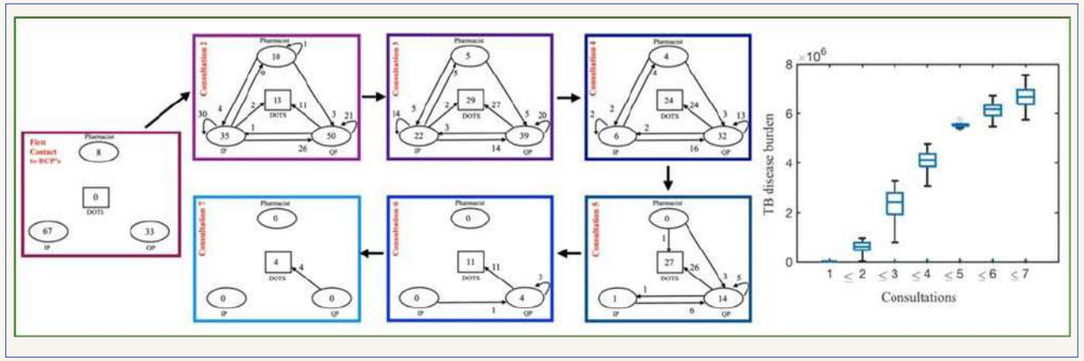


Treatment-Seeking behaviour and TB burden

This very interesting ongoing research project focuses on treatment-seeking behavior in tuberculosis (TB). TB predominantly affects impoverished populations, who often seek advice from informal medical practitioners before consulting DOTS centers. This pattern of multiple consultations and switching between different practitioners significantly impacts the TB burden.

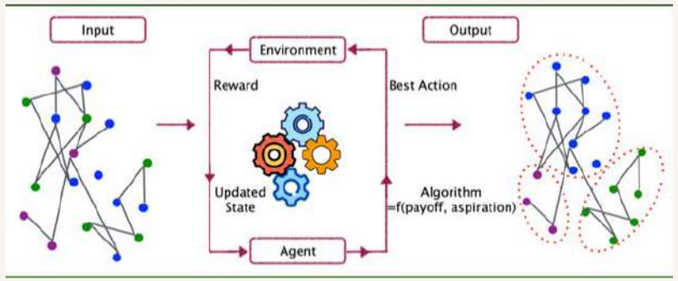
Our data-driven modeling suggests that this behavior could lead to an approximately 340-fold increase from the baseline estimate.

The study aims to develop an optimal framework to minimize the impact of this behavior on the current TB burden.



Reinforcement Learning and Vaccination Decision

Another area of compelling research focuses on reinforcement learning in medical decision-making, particularly in the context of voluntary vaccination during an outbreak. The decision to vaccinate is influenced by various factors, including the severity of the disease, peer pressure, social media opinions, vaccine efficacy, and more.



The research has developed models that leverage Deep Learning, complex networks, and game theory to design optimal strategies for vaccine campaigns for effective control of transmission of infection.

Please share some insights on your collaborations with Industry and Academia?

I have established several impactful collaborations with leading institutions across globe, including the University of Sydney, the University of Texas, Heidelberg University, the University of Bonn, Waterloo University, the Global Health Institute in Antwerp, and the National Institute of Public Health in Burkina Faso.

These partnerships are pivotal for advancing research on infectious disease modelling and sustainability facilitating joint research on infectious disease and environmental health impacts, aligning with several SDGs.

I have an ongoing project to study the impact of human migration on malaria endemicity in Sub-Saharan Africa in partnership with the University of Bonn, Germany. The project is being funded by the Department of Science and Technology - DAAD grant.

I am also leading an intra-school project titled *Indian Pollution Scenarios of PM10 and PM2.5: Local Measurement to Regional Emission Modelling* with the School of Engineering. This project takes a quantitative approach to analyzing the spatiotemporal dynamics of Indian air pollution and its public health outcomes, contributing to the Sustainable Development Goals (SDGs) for clean air and health. These collaborations and projects not only enhance the quality of our research but also ensure that our findings have practical, long-term impacts on sustainability.

Our vision for a sustainable future necessitates addressing critical health challenges and environmental impacts through innovative research. My work contributes to several UN Sustainable Development Goals (SDGs) by utilizing mathematical modeling to enhance public health outcomes and environmental sustainability.

RECENT PUBLICATIONS

1. Kumar, V., **Bhattacharyya, S**.: Nonlinear effect of sentiments and opinion sharing on vaccination decision in face of an outbreak: A multiplex network approach. Chaos, Solitons & Fractals 175, 114014 (2023).

2. **Bhattacharyya, S**., Vinkeles Melchers, N.V., Siewe Fodjo, J.N., Vutha, A., Cof- feng, L.E., Logora, M.Y., Colebunders, R., Stolk, W.A.: Onchocerciasis-associated epilepsy in maridi, south sudan: Modelling and exploring the impact of control measures against river blindness. PLoS Neglected Tropical diseases 17(5), 0011320 (2023).

3. Dwivedi, S., Perumal, S.K., Kumar, S., **Bhattacharyya, S**., Kumari, N.: Impact of cross border reverse migration in delhi – up region of India during COVID-19 lockdown. Computational and Mathematical Biophysics 11(1), 20220151 (2023) 35.

4. Malik, Bhawna, and **Samit Bhattacharyya.** "A stochastic model of antibiotic misuse, economy, and drug resistance: relating mutant extinction probability to socioeconomic and epidemiological factors." Mathematical and Computer Modelling of Dynamical Systems 29.1 (2023): 236-264.

5. Malik, Bhawna, Habib Hasan Farooqui, and **Samit Bhattacharyya.** "Disparity in socio-economic status explains the pattern of self-medication of antibiotics in India: understanding from a game-theoretic perspective." Royal Society Open Science 9.2 (2022): 211872.

6. Laxmi, Calistus N. Ngonghala, and **Samit Bhattacharyya**. "An evolutionary game model of individual choices and bed net use: elucidating key aspect in malaria elimination strategies." Royal Society Open Science 9.11 (2022): 220685.

One of the critical elements of research in sustainability is sustainability itself. How do you think your work is creating a long-term impact on sustainability?

My work is creating a long-term impact on sustainability by addressing critical challenges through innovative mathematical models and solutions. By developing predictive models for infectious diseases and optimizing health interventions, I contribute to more effective and sustainable public health strategies.

My research essentially provides insights to create resilient health systems that can adapt to evolving challenges. Additionally, my focus on pollution control modelling supports environmental sustainability by providing data-driven insights for effective policymaking and pollution reduction strategies.

These contributions not only enhance our understanding of complex systems but also promote sustainable practices that have enduring benefits for both human health and the environment.

Dr. Samit Bhattacharya (in center), with his research Students
left to right: Preeti Saini, Manalipadam Lakshmi, Monica Dhyani, Samit Bhattacharyya, Hari Kirpal, Viney Kumar, Saif Abbas

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Shiv Nadar Institution of Eminence is fully committed to the UN Sustainable Development Goals (SDGs). We have embraced a four-pronged strategy for SDGs through **teaching, research, our core institutional practices, and partnerships.**

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