International Journal of Engineering, Management and Humanities (IJEMH)
Volume 7, Issue 4, Jul.-Aug., 2026 pp: 205-224 ISSN: 2584-2145 www.ijemh.com

Advances in Health Engineering and Sciences in South Asia: Integration of Nanotechnology, MHD, Mathematical, Social and Managerial Perspectives

Rakesh Manilal H. Patel
Department of Mathematics, Government Science College, Sector-15, Gandhinagar, Gujarat, India,

Dr. Haresh D. Chaudhari
Department of History, Government Arts College, Kawant, Gujarat, India

Dr. Anand K. Acharya
Department of Sociology, Government Arts College, Bayad, Gujarat, India

Dr. Naynesh A. Gadhavi
Department of Sociology, Gujarat Arts & Science College, Ahmedabad, Gujarat, India

Dr. Bharatkumar N. Valani
Department of Mathematics, Government Science College, Sector-15, Gandhinagar, Gujarat, India

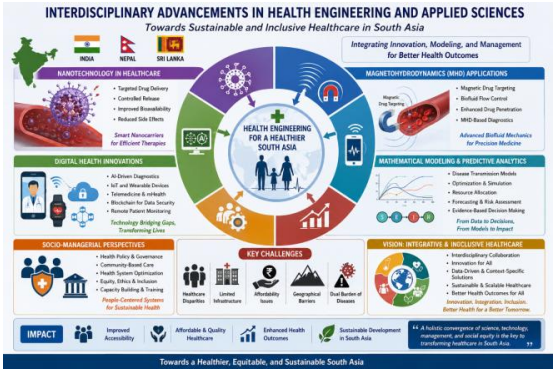
Dr. Dhinesha Ruwanthi Perera
Senior Lecturer, Department of Management and Finance
General Sir John Kotelawala Defence University, Sri Lanka

Date of Submission: 24-07-2026 Date of Acceptance: 07-08-2026

Abstract
Health engineering and applied sciences have witnessed profound and transformative advancements across South Asia, particularly in India, Nepal, and Sri Lanka, over the past few decades. These developments are driven by the convergence of multidisciplinary domains including biomedical engineering, nanotechnology, magnetohydrodynamics (MHD), digital health technologies, mathematical modeling, and socio-managerial frameworks. Such integration has enabled innovative, scalable, and cost-effective solutions tailored to the unique healthcare challenges of the region, which include high population density, limited healthcare infrastructure, socio-economic disparities, and a dual burden of communicable and non-communicable diseases. In particular, the incorporation of nanotechnology has revolutionized drug delivery systems by enabling targeted, controlled, and efficient therapeutic interventions, while MHD principles have opened new avenues in biofluid mechanics, including magnetic drug targeting and controlled blood flow dynamics. Simultaneously, digital health innovations—such as artificial intelligence (AI), Internet of Things (IoT), telemedicine, and blockchain—are enhancing diagnostic accuracy, remote patient monitoring, and secure health data management, thereby bridging gaps in accessibility, especially in rural and geographically challenging regions. Mathematical modeling plays a central role in this interdisciplinary framework by providing predictive, analytical, and optimization-based tools for understanding disease dynamics, designing treatment protocols, and improving healthcare resource allocation. Epidemiological models, optimization techniques, and system dynamics approaches contribute significantly to evidence-based policymaking and strategic healthcare planning. Furthermore, socio-managerial perspectives, including health policy design, governance, and community-based healthcare delivery systems, are essential in ensuring the effective implementation and sustainability of technological innovations. This review synthesizes recent interdisciplinary advancements in health engineering, with a particular emphasis on predictive modeling, nanotechnology-enabled

International Journal of Engineering, Management and Humanities (IJEMH)
Volume 7, Issue 4, Jul.-Aug., 2026 pp: 205-224 ISSN: 2584-2145 www.ijemh.com

targeted drug delivery, MHD-based biomedical applications, and healthcare system optimization. It critically examines the interplay between technological innovation and socio-economic determinants of health, highlighting disparities in healthcare access and outcomes across the region. The study underscores the urgent need for region-specific, data-driven, and inclusive healthcare frameworks that are adaptive to local contexts. Ultimately, the paper advocates for a holistic and integrative approach to health engineering that combines scientific innovation with managerial efficiency and social equity. Such an approach is crucial for improving accessibility, affordability, and quality of healthcare services in low- and middle-income countries (LMICs), thereby contributing to sustainable healthcare development and enhanced public health outcomes in South Asia.



Keywords
Health Engineering, Nanotechnology, MHD Flow, Mathematical Modeling, South Asia, Social Determinants, Healthcare Management, Digital Health, PHC

I. Introduction

The South Asian region, comprising over 1.7 billion people, faces a dual burden of communicable and non-communicable diseases alongside socio-economic disparities in healthcare access. India, Nepal, and Sri Lanka present interconnected healthcare challenges shaped by demographic diversity, limited resources, and evolving epidemiological trends. Health engineering has evolved through the convergence of biomedical sciences, applied mathematics, nanotechnology, and engineering technologies. Advances such as AI-driven diagnostics, nanomedicine, and MHD-based biofluid modeling are redefining healthcare delivery. Mathematical modeling plays a central role in prediction, optimization, and policy planning.

II. Literature Review

Health engineering has evolved from conventional biomedical engineering toward an interdisciplinary domain integrating mathematical modeling, nanotechnology, magnetohydrodynamics (MHD), digital healthcare, computational intelligence, and socio-managerial sciences. The literature demonstrates a gradual progression from fundamental theoretical concepts developed during the 1970s to modern intelligent healthcare systems driven by artificial intelligence, predictive analytics, and sustainable healthcare policies. This review categorizes previous studies into thematic areas relevant to the present work.

Foundations of Biomedical Engineering and Magnetohydrodynamics

The modern foundation of biomedical engineering was established during the 1970s through studies involving physiological transport phenomena, electromagnetic interactions, and biological flow systems. Early investigations by Blakemore (1975) on magnetotactic bacteria revealed the biological significance of magnetic nanoparticles and their interaction with external magnetic fields. Griffiths (1975) investigated negative resistance effects in collapsible biological tubes, providing important insights into cardiovascular biomechanics. Gold and Schuder (1975) analyzed electric field distributions in biological tissues using electrolytic tank techniques, laying the groundwork for computational bioelectromagnetics. Simultaneously, Gupta and Gupta (1975) introduced analytical studies on magnetohydrodynamic channel flow incorporating chemical reactions, demonstrating the potential application of MHD principles in physiological transport systems. These investigations collectively established the theoretical basis for later developments in magnetic drug targeting, blood flow control, and biomedical fluid mechanics. The engineering foundations of magnetohydrodynamics were strengthened by the classical works of Cramer and Pai (1975), Shercliff (1979), Moreau (1990), and Davidson (2001). Their comprehensive treatments of electrically conducting fluids continue to serve as fundamental references for biomedical MHD research, especially in ferrofluid lubrication, blood flow regulation, and magnetic nanoparticle transport. **Evolution of Nanotechnology and Targeted Drug Delivery**

Nanotechnology emerged as a revolutionary discipline following Taniguchi's foundational concept during the mid-1970s. The pharmaceutical application of nanoparticles began with Speiser

International Journal of Engineering, Management and Humanities (IJEMH)
Volume 7, Issue 4, Jul.-Aug., 2026 pp: 205-224 ISSN: 2584-2145 www.ijemh.com

(1976), who proposed nanoparticle-based drug delivery systems capable of improving therapeutic efficiency. Gregoriadis (1976) and later Szoka and Papahadjopoulos (1980) pioneered liposome-mediated drug delivery, introducing controlled and targeted release mechanisms that significantly enhanced drug bioavailability while minimizing systemic toxicity. Ringsdorf's polymer-drug conjugate theory further expanded the understanding of polymeric carriers and structure-property relationships. The development of polymeric nanoparticles by Couvreur and Vauthier (1990) marked another milestone in nanomedicine by enabling site-specific drug delivery. Freitas (1999) subsequently proposed the concept of nanomedicine, envisioning molecular machines capable of diagnosis and treatment at the cellular level. Comprehensive reviews by Sahoo et al. (2007) demonstrated the enormous potential of nanotechnology in cancer therapy, tissue engineering, imaging, and regenerative medicine. Buzea et al. (2008) expanded this understanding by evaluating nanoparticle toxicity and biosafety, highlighting challenges associated with clinical translation. More recently, Noah and Ndangili (2021) emphasized environmentally sustainable ("green") nanotechnology approaches for biomedical applications. These studies collectively indicate that nanotechnology has transformed healthcare from generalized treatment strategies toward precision medicine.

Magnetohydrodynamics in Biomedical Applications

Magnetohydrodynamics has emerged as one of the most promising tools for biomedical engineering because human blood behaves as an electrically conducting fluid under external magnetic fields. Classical studies by Raeder (1975) and Yamanishi (1975) primarily focused on industrial MHD systems. However, subsequent developments extended these principles to biomedical applications including:

- magnetic drug targeting,
- magnetic hyperthermia,
- controlled blood circulation,
- artificial organs,
- targeted chemotherapy,
- ferrofluid lubrication,
- implantable biomedical devices.

Davidson (2001) demonstrated that magnetic field interactions significantly influence electrically conducting fluid behavior, providing the theoretical framework for biomedical transport modeling. Recent research increasingly integrates MHD with nanoparticle transport, enabling precise therapeutic delivery while minimizing adverse effects.

Mathematical Modeling in Health Engineering

Mathematical modeling has become indispensable in modern healthcare because it enables prediction, optimization, simulation, and evidence-based decision making. Murray (1989) introduced one of the most influential mathematical biology frameworks describing population dynamics, infectious diseases, tumor growth, and physiological processes using nonlinear differential equations. Keener and Sneyd (1998) expanded mathematical physiology by modeling electrophysiology, cardiac dynamics, nerve conduction, and cellular transport mechanisms. Banks and Tran (2009) demonstrated the importance of combining experimental observations with mathematical modeling to improve engineering system reliability. Recent advances by Farsad et al. (2014) introduced molecular communication models inspired by biological systems, enabling nanoscale information transfer for future biomedical devices.
These mathematical approaches are now widely used for:

- epidemiological forecasting,
- optimization of healthcare resources,
- disease progression analysis,
- personalized medicine,
- precision diagnostics,
- digital twin healthcare systems.

Nanofluid Heat Transfer and Biomedical Transport

Nanofluid research has significantly enhanced biomedical thermal management and drug transport. Choi (1995) introduced nanofluids by dispersing nanoparticles into conventional fluids, demonstrating remarkable enhancement in thermal conductivity. Buongiorno (2006) established the governing transport mechanisms including:

- Brownian diffusion,
- thermophoresis,
- particle migration,
- nanoparticle-fluid interaction.

Later investigations by Khan and Pop (2010) and Nadeem and Lee (2012) developed mathematical models describing nanofluid flow over stretching surfaces, providing analytical solutions relevant to biomedical cooling, tissue heating, and microfluidic systems.
Nanofluid modeling now plays a significant role in:

- cancer hyperthermia,
- artificial organ cooling,

International Journal of Engineering, Management and Humanities (IJEMH)
Volume 7, Issue 4, Jul.-Aug., 2026 pp: 205-224 ISSN: 2584-2145 www.ijemh.com

- biosensors,
- lab-on-chip devices,
- targeted nanoparticle transport.

Health Systems Engineering and Socio-Managerial Perspectives

Technological advancement alone cannot ensure effective healthcare delivery without appropriate governance, policy frameworks, and management systems. World Health Organization reports (2000–2023) consistently emphasize:

- universal health coverage,
- primary healthcare,
- health equity,
- resilient health systems,
- digital transformation.

Similarly, World Bank reports (2017–2024) highlight healthcare financing challenges faced by low- and middle-income countries (LMICs), particularly across South Asia. Gebeshuber and Majlis (2010) proposed biomimetic nanotechnology as a sustainable solution to global health challenges by integrating biological inspiration with engineering innovation. Recent literature increasingly recognizes healthcare as a socio-technical system requiring interdisciplinary collaboration among engineers, clinicians, policymakers, economists, and social scientists.

Hydromagnetic Lubrication and Tribological Modeling

An extensive body of research has been contributed by Patel, Deheri, Adeshara, Vadher, and collaborators on hydromagnetic lubrication and ferrofluid-based tribological systems. Beginning with Adeshara et al. (2020), mathematical models investigated hydromagnetic squeeze films in rough elliptical plates, truncated conical plates, and porous structures. These studies demonstrated that magnetic fields significantly improve load-carrying capacity while reducing friction and wear. Vashi et al. (2020) incorporated the Neuringer-Rosensweig ferrofluid model with couple stress effects, whereas Vadher et al. (2020) investigated viscosity variation and velocity slip in conducting porous circular plates. Subsequent publications between 2021 and 2025 systematically expanded these models by incorporating:

- surface roughness,
- deformation,
- porous media,
- Kozeny-Carman permeability,
- Rabinowitz fluids,
- micropolar fluids,
- variable viscosity,
- velocity slip,
- piezo-viscous effects,
- rotating plates,
- annular geometries,
- finite journal bearings,
- slider bearings,
- conical bearings.

These investigations consistently reported improvements in lubrication efficiency, bearing stability, friction reduction, and load capacity through optimized hydromagnetic configurations. Although primarily tribological, these mathematical formulations provide transferable methodologies applicable to biomedical lubrication systems, artificial joints, prosthetic implants, cardiovascular devices, and microfluidic engineering.

Socio-Mathematical Modeling and Healthcare Decision Support

Recent studies by Acharya et al. (2024, 2025), Patel et al. (2025), Perera and Patel (2025), and collaborators have extended mathematical modeling beyond engineering into healthcare management, sociology, education, governance, and policy analysis. These works introduced quantitative frameworks for:

- disease prevention,
- infection awareness,
- healthcare intervention assessment,
- political and behavioral modeling,
- educational planning,
- managerial decision-making,
- vocational development,
- smart governance,
- mathematical sociology.

Patel and Perera (2025, 2026) further demonstrated the integration of optimization, managerial science, and computational intelligence into interdisciplinary research involving healthcare, manufacturing, and social systems. Such contributions illustrate the growing importance of combining mathematical rigor with socio-managerial perspectives to support sustainable healthcare policies and evidence-based decision-making.

Research Gap

Despite substantial progress across individual disciplines, several important research gaps remain:

- Existing studies largely investigate nanotechnology, MHD, mathematical modeling, digital healthcare, and health policy independently, with limited interdisciplinary integration.

International Journal of Engineering, Management and Humanities (IJEMH)
Volume 7, Issue 4, Jul.-Aug., 2026 pp: 205-224 ISSN: 2584-2145 www.ijemh.com

- Few reviews comprehensively examine the combined role of predictive modeling, MHD, nanotechnology, and socio-managerial frameworks within South Asian healthcare systems.
- Most mathematical models focus on engineering optimization rather than healthcare implementation, accessibility, and policy implications.
- Region-specific analyses addressing the healthcare challenges of India, Nepal, and Sri Lanka remain scarce.
- Limited attention has been given to integrating digital health technologies (AI, IoT, blockchain, telemedicine) with mathematical modeling and biomedical engineering into unified healthcare frameworks.
- Sustainable and equitable implementation strategies for low- and middle-income countries continue to require greater emphasis.

III. Summary

The literature demonstrates a clear evolution from classical biomedical engineering and magnetohydrodynamics toward highly integrated health engineering systems combining nanotechnology, computational modeling, digital health, and socio-managerial sciences. Foundational contributions established the theoretical basis for biofluid mechanics, targeted drug delivery, and mathematical physiology, while contemporary studies have expanded these concepts through artificial intelligence, predictive analytics, ferrofluid mechanics, and interdisciplinary optimization. Nevertheless, a comprehensive synthesis specifically addressing South Asian healthcare through an integrated mathematical, engineering, technological, and managerial perspective remains limited. The present review seeks to bridge this gap by proposing a holistic framework that combines predictive mathematical modeling, nanotechnology-enabled therapeutics, MHD-based biomedical applications, digital health innovations, and evidence-based health governance to support sustainable and inclusive healthcare development in India, Nepal, and Sri Lanka.

Advances in Health Engineering and Technology
Biomedical Engineering and Low-Cost Innovations
Recent innovations emphasize affordability and scalability:

- Low-cost diagnostic devices
- Portable imaging and telemedicine tools
- Wearable health monitoring systems

Key pillars include:

1. Affordable hardware
2. ICT-based healthcare systems
3. Mobile health (mHealth) platforms

Digital Health and Artificial Intelligence

- AI-based disease prediction models
- IoT-enabled remote patient monitoring
- Blockchain for secure health records

These technologies enhance efficiency and expand healthcare access in rural and remote regions.

Nanotechnology in Health Engineering
Nanoparticle-Based Drug Delivery
Nanotechnology enables:

- Targeted drug delivery
- Controlled and sustained release
- Improved bioavailability

Nanoformulations such as liposomes, dendrimers, and polymeric nanoparticles enhance therapeutic efficiency and reduce toxicity.
Mathematical Modeling in Nanomedicine
Mathematical models assist in:

- Nanoparticle transport and diffusion
- Pharmacokinetics and drug distribution
- Dosage optimization

A generalized transport model:

$$\partial C/\partial t = D\nabla^2 C - v\nabla C + R(C)$$

MHD Flow and Biomedical Applications
Role of MHD in Biofluid Mechanics
MHD studies electrically conducting fluids such as blood under magnetic fields. Applications include:

- Magnetic drug targeting
- Blood flow control
- Cancer treatment using magnetic nanoparticles

MHD Nanofluid Models
Generalized MHD equation:

$$\rho(\partial u/\partial t) + u\nabla u = -\nabla p + \mu\nabla^2 u + \sigma B^2 u$$

Where the Lorentz force term enables magnetic control of fluid motion.
Coupling Nanotechnology and MHD
Integration leads to magnetically controlled nanomedicine:

- Magnetic nanoparticles guided to target sites
- Enhanced drug localization
- Reduced systemic toxicity

This coupling significantly improves therapeutic precision, especially in cancer treatment.

International Journal of Engineering, Management and Humanities (IJEMH)
Volume 7, Issue 4, Jul.-Aug., 2026 pp: 205-224 ISSN: 2584-2145 www.ijemh.com

Mathematical Modeling in Health Sciences

Epidemiological Modeling

$$dI/dt = \beta SI - \gamma$$

Used for:

- Disease transmission analysis
- Vaccination strategies
- Epidemic control

Optimization Models

- Linear programming for resource allocation
- Game theory for policy decisions
- Fuzzy logic for uncertainty handling

System Dynamics

Simulates long-term healthcare behavior integrating:

- Population growth
- Disease burden
- Infrastructure

Social Determinants of Health in South Asia

Health outcomes are influenced by:

- Poverty
- Education
- Gender inequality
- Cultural and caste systems

Significant disparities exist in maternal healthcare, rural access, and urban healthcare quality.

Managerial Perspectives in Health Systems

Primary Health Care (PHC)

- Cost-effective and preventive
- Community-oriented

Community Health Workers (CHW)

- Bridge rural healthcare gaps
- Provide essential maternal and child services

Policy and Governance

Challenges include:

- Fragmented systems
- Limited funding
- High out-of-pocket expenditure

Solutions:

- Integrated healthcare models
- Public-private partnerships
- Data-driven governance

Indo–Nepal–Sri Lanka Comparative Insights

Aspect	India	Nepal	Sri Lanka
Infrastructure	Diverse	Limited rural	Strong public system
Digital Health	Rapid	Emerging	Moderate
Inequality	High	High	Lower
PHC	Moderate	Developing	Strong

Sri Lanka demonstrates better health indicators due to strong public health policies.

Integrated Mathematical–Engineering–Social Framework

$$H(t) = \alpha N(t) + \beta MHD(t) + \gamma S(t) + \delta G(t)$$

Where:

- $(N(t))$: Nanotechnology
- $(MHD(t))$: Magnetic biofluid models
- $(S(t))$: Social determinants
- $(G(t))$: Governance

Applications:

- Policy optimization
- Healthcare forecasting
- Strategic planning

Research Gaps

- Limited clinical validation of MHD-based therapies
- Lack of region-specific datasets
- Weak interdisciplinary integration
- Poor linkage between policy and modeling
- Underrepresentation of rural populations

Future Directions

- AI-driven personalized healthcare
- Smart magnetic drug delivery systems
- Hybrid socio-fuzzy mathematical models
- Expansion of telemedicine
- Cross-border research collaboration

Conclusions

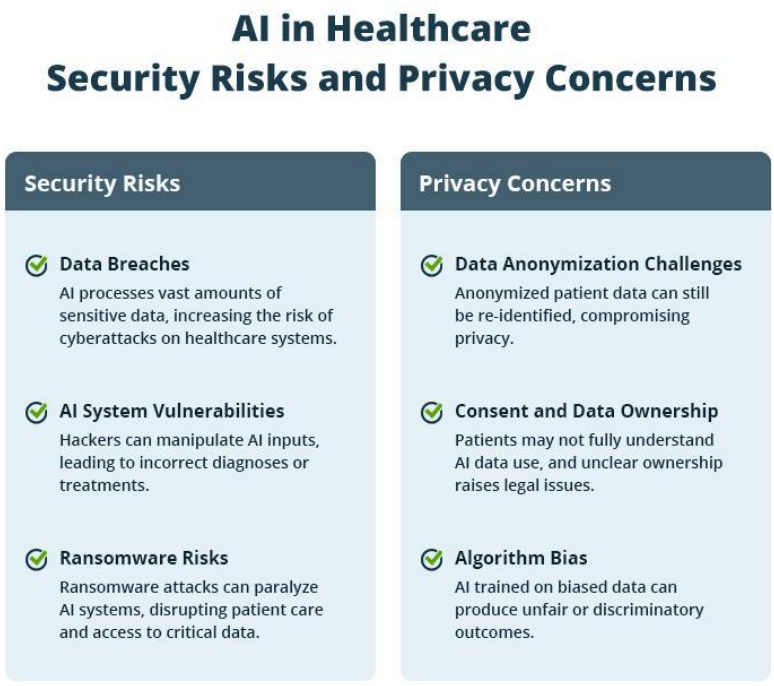
The integration of nanotechnology, MHD flow modeling, mathematical frameworks, and socio-managerial strategies represents a transformative approach to health engineering in South Asia. India, Nepal, and Sri Lanka must adopt interdisciplinary, data-driven, and inclusive approaches to overcome disparities and achieve sustainable healthcare development.

International Journal of Engineering, Management and Humanities (IJEMH)
Volume 7, Issue 4, Jul.-Aug., 2026 pp: 205-224 ISSN: 2584-2145 www.ijemh.com

FUTURE RESEARCH DIRECTIONS (MULTI-DISCIPLINARY FRAMEWORK)

1. SOCIAL SCIENCE RESEARCH DIRECTIONS





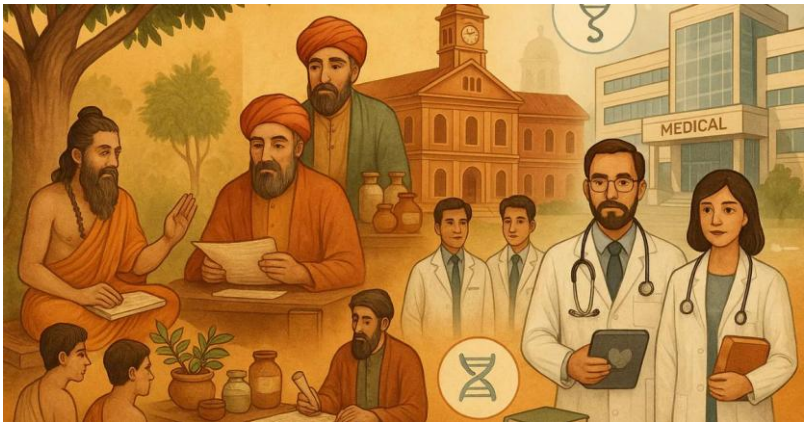
Key Themes:

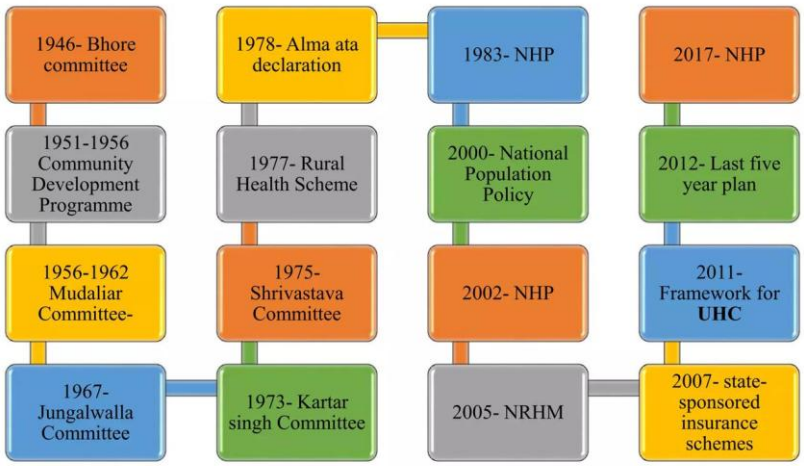
- Socio-Fuzzy Health Modeling
  - Develop hybrid indices combining trust, accessibility, governance, and mental health.

International Journal of Engineering, Management and Humanities (IJEMH)
Volume 7, Issue 4, Jul.-Aug., 2026 pp: 205-224 ISSN: 2584-2145 www.ijemh.com

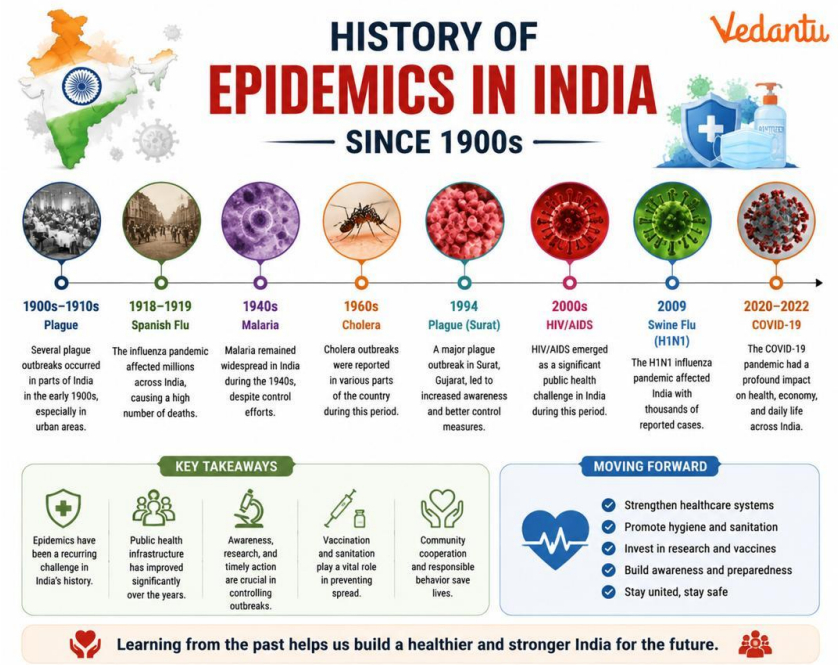
- Example Model:
  SFI = w1T + w2E + w3M + w4G
- Digital Divide & Health Equity
  - Study AI, IoT, telemedicine adoption gaps in rural vs urban populations.
  - Behavioral acceptance models for digital healthcare.
- Health Governance & Policy Analytics
  - Evaluate policy efficiency using data-driven social models.
  - Comparative studies: India–Nepal–Sri Lanka.
- Ethics in AI-driven Healthcare
  - Privacy, algorithmic bias, and socio-cultural acceptance.

2. HISTORY RESEARCH DIRECTIONS





International Journal of Engineering, Management and Humanities (IJEMH)
Volume 7, Issue 4, Jul.-Aug., 2026 pp: 205-224 ISSN: 2584-2145 www.ijemh.com





International Journal of Engineering, Management and Humanities (IJEMH)
Volume 7, Issue 4, Jul.-Aug., 2026 pp: 205-224 ISSN: 2584-2145 www.ijemh.com

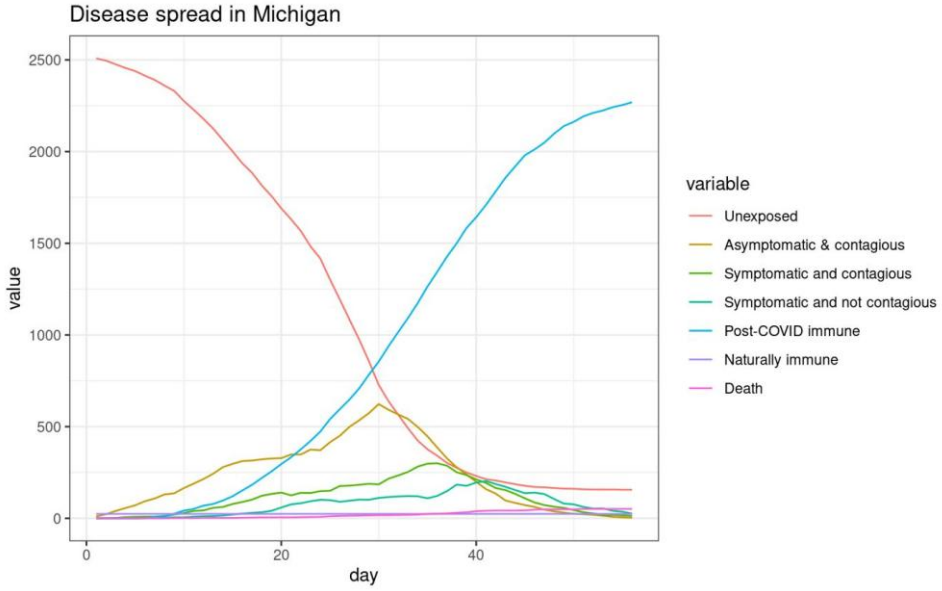


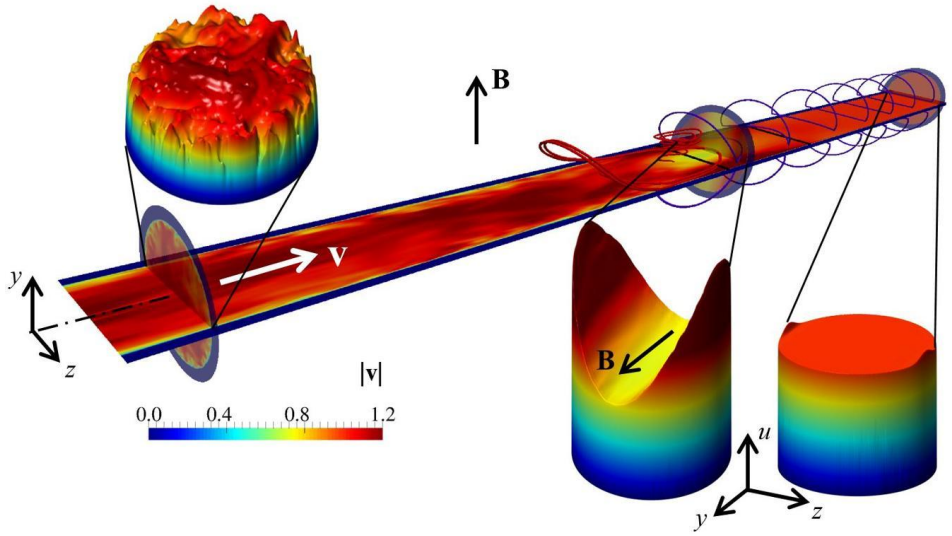
Key Themes:

- Evolution of Healthcare Systems
  - From Ayurveda to AI-based healthcare systems.
  - Colonial vs post-independence health reforms.
- Historical Epidemiology
  - Comparative study of pandemics (Plague, Spanish Flu, COVID-19).
- Technological Transitions in Medicine
  - Shift from traditional healing to nanomedicine and MHD applications.
- Archival Data Digitization
  - Creating historical health datasets for predictive modeling.

International Journal of Engineering, Management and Humanities (IJEMH)
Volume 7, Issue 4, Jul.-Aug., 2026 pp: 205-224 ISSN: 2584-2145 www.ijemh.com

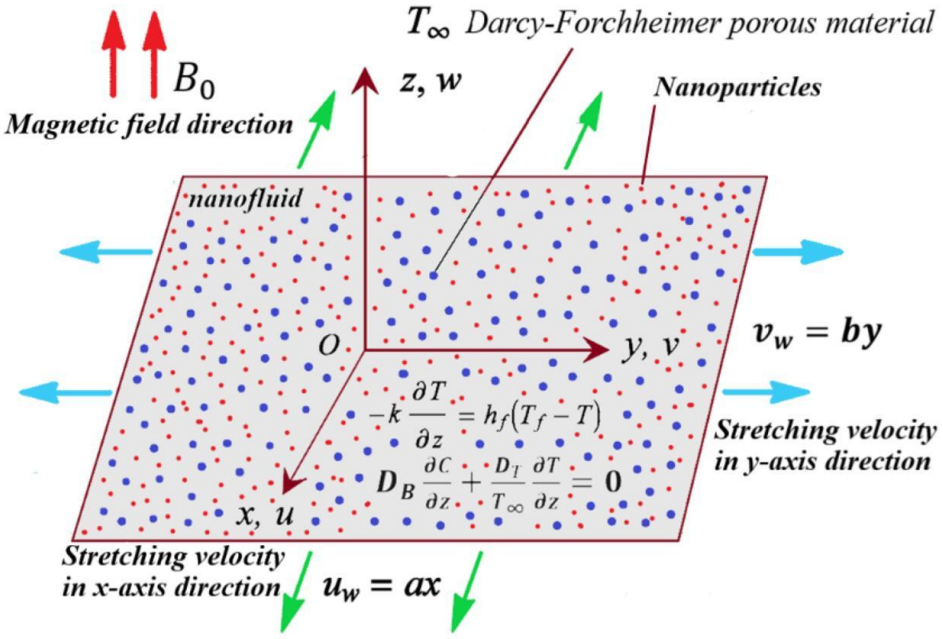
3. MATHEMATICS RESEARCH DIRECTIONS

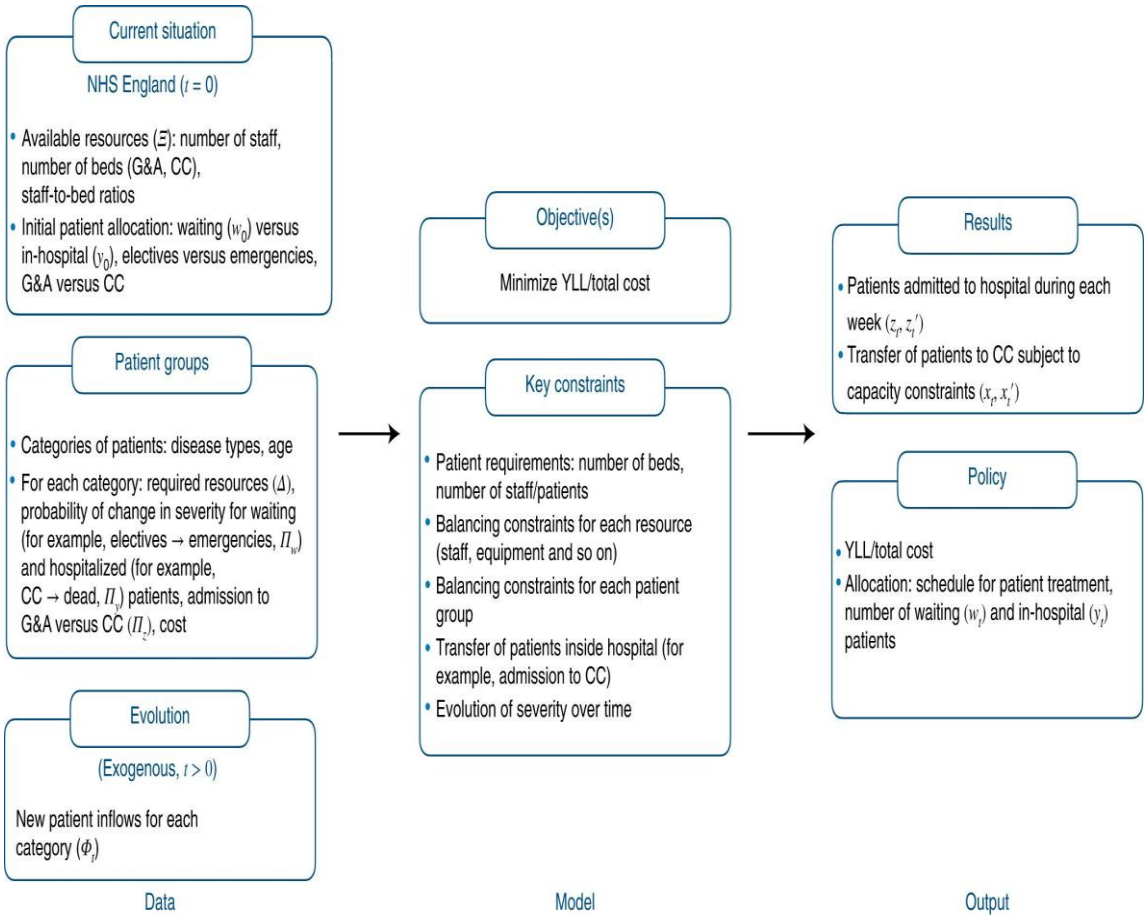




Current lines and velocity profiles for *Ha*=2000, *Re*=20000

International Journal of Engineering, Management and Humanities (IJEMH)
Volume 7, Issue 4, Jul.-Aug., 2026 pp: 205-224 ISSN: 2584-2145 www.ijemh.com





International Journal of Engineering, Management and Humanities (IJEMH)
Volume 7, Issue 4, Jul.-Aug., 2026 pp: 205-224 ISSN: 2584-2145 www.ijemh.com

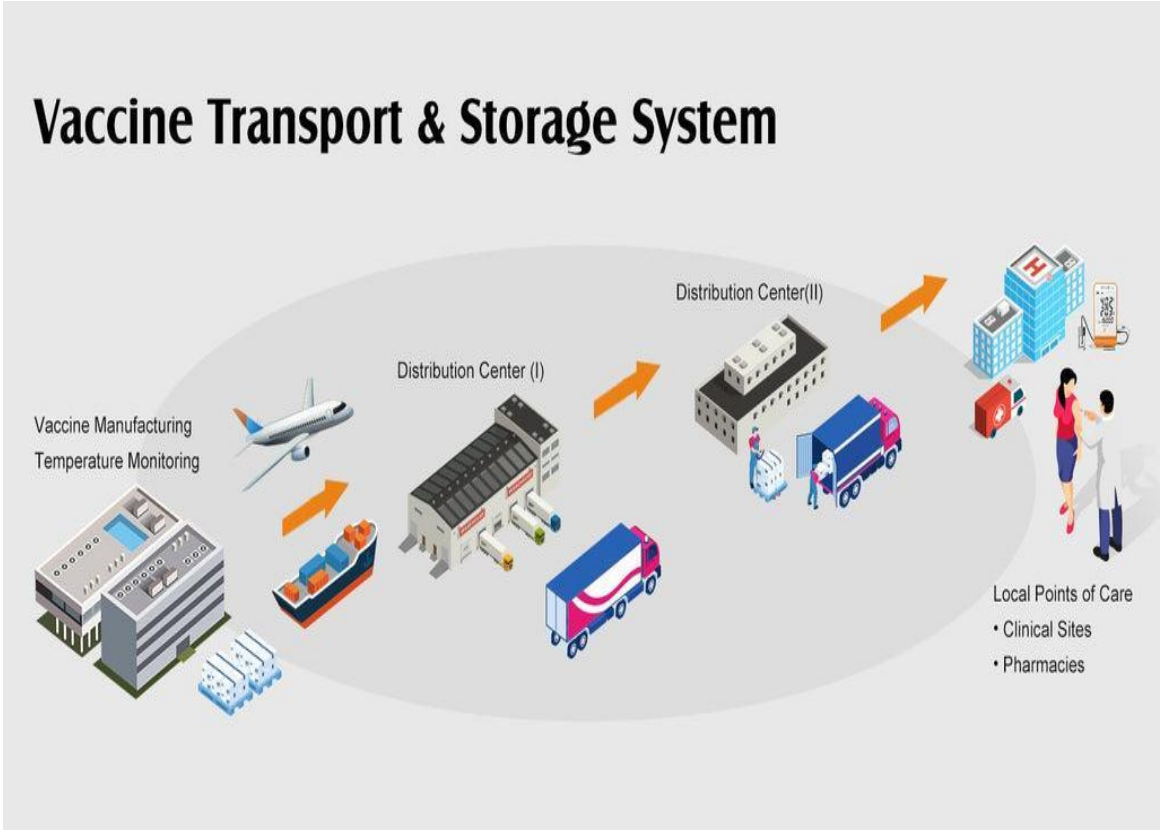
Key Themes:

- Epidemiological Modeling
  - Advanced SIR/SEIR models with stochastic and fuzzy extensions.

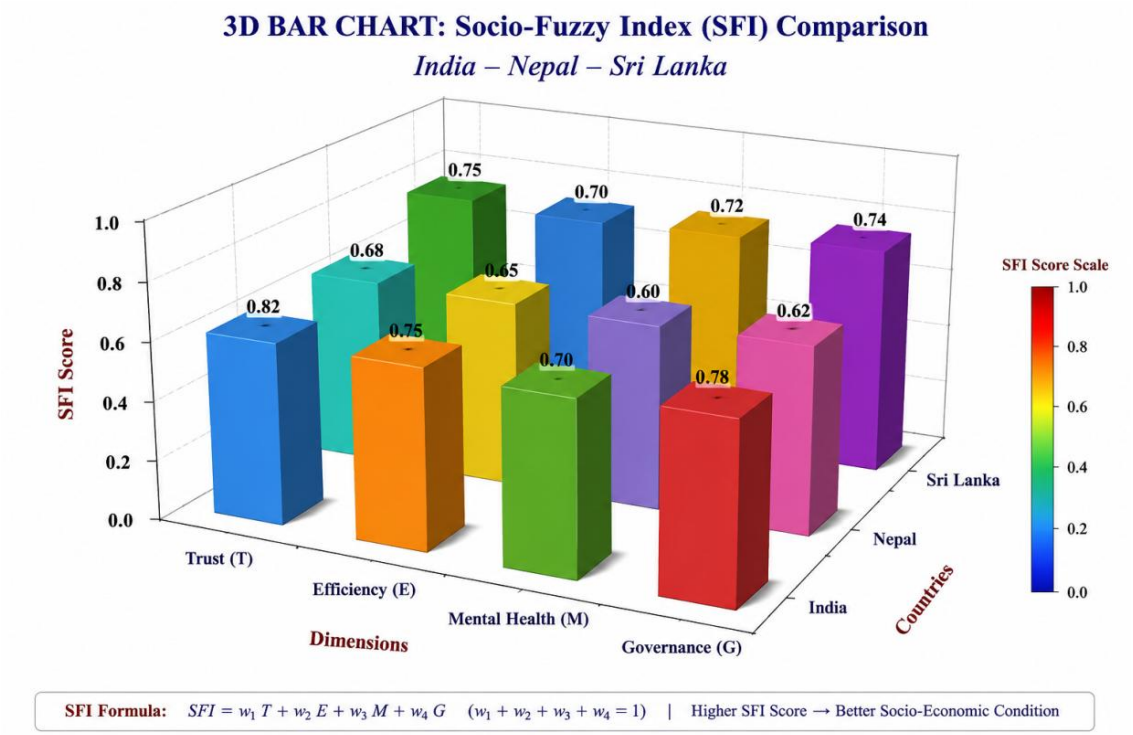
  $dS/dt = -\beta SI$, $dI/dt = \beta SI - \gamma I$
- Magnetohydrodynamic (MHD) Biofluid Models
  - Blood flow under magnetic field influence.

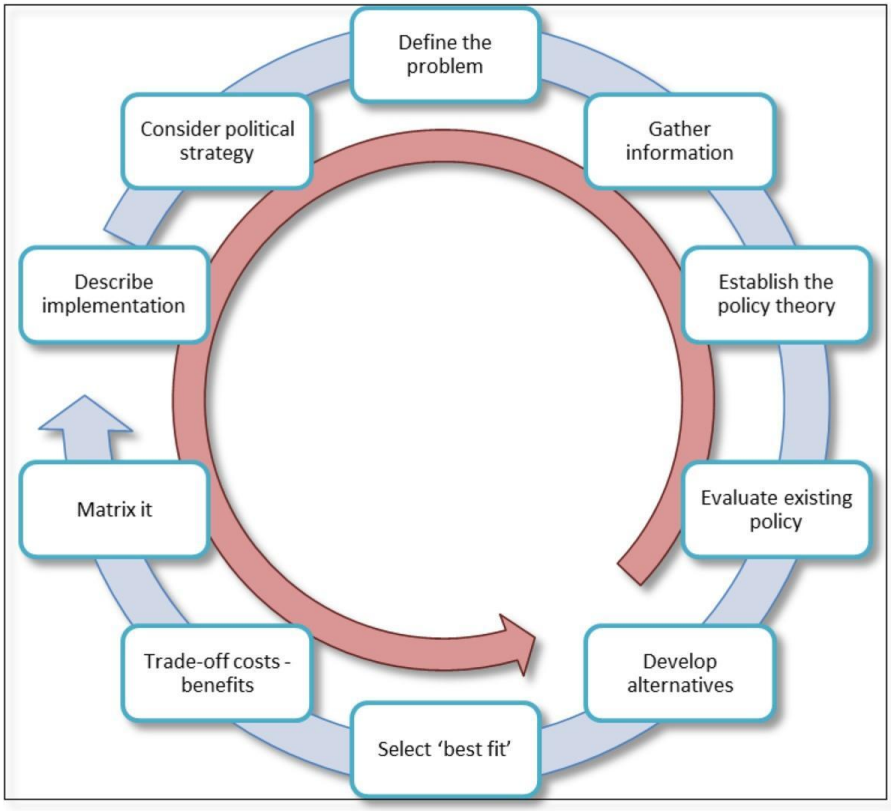
  $\rho(du/dt) = -\nabla p + \mu\nabla^2 u + J \times B$
- Nanofluid Dynamics
  - Drug delivery using nanoparticle transport equations.
- Optimization & Operations Research
  - Hospital resource allocation, vaccine distribution models.
- Socio-Mathematical Systems
  - Integration of human behavior into mathematical frameworks.

4. MANAGEMENT RESEARCH DIRECTIONS

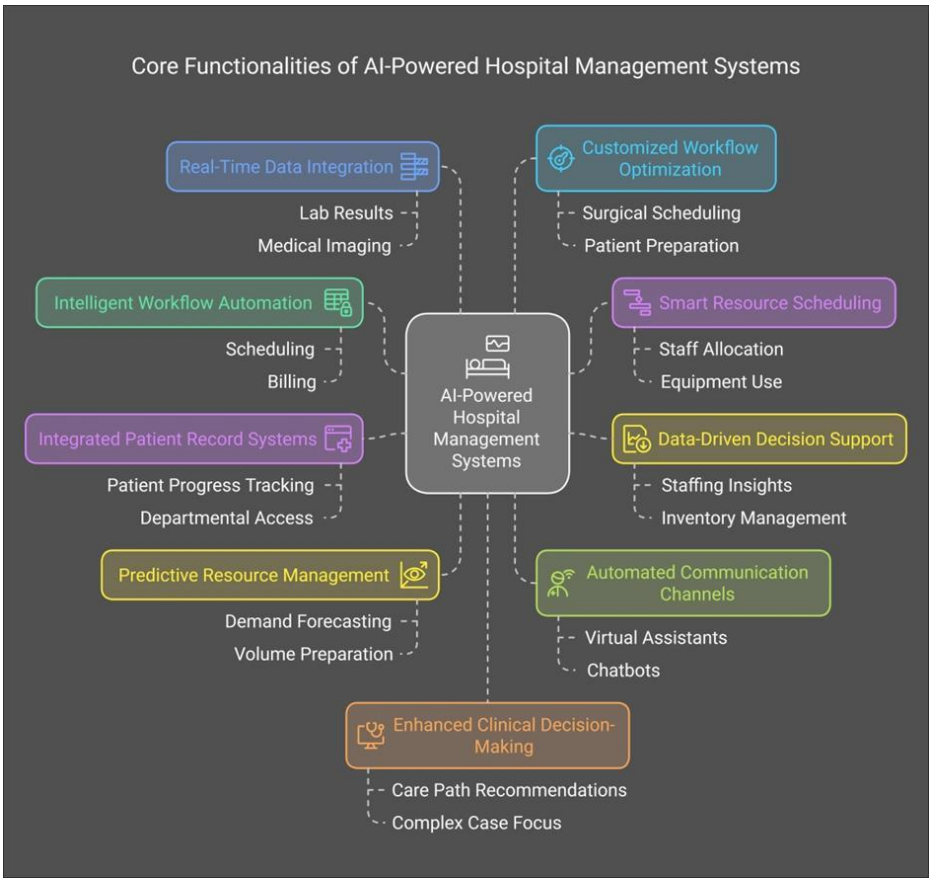


International Journal of Engineering, Management and Humanities (IJEMH)
Volume 7, Issue 4, Jul.-Aug., 2026 pp: 205-224 ISSN: 2584-2145 www.ijemh.com





International Journal of Engineering, Management and Humanities (IJEMH)
Volume 7, Issue 4, Jul.-Aug., 2026 pp: 205-224 ISSN: 2584-2145 www.ijemh.com





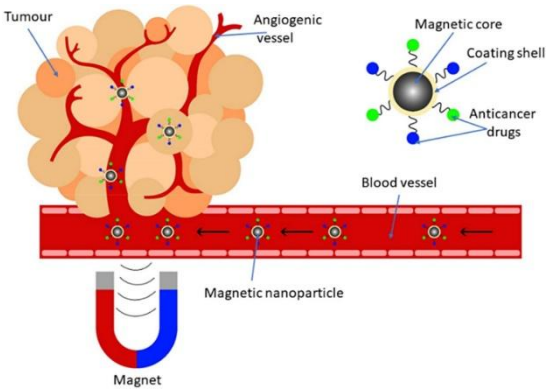
International Journal of Engineering, Management and Humanities (IJEMH)
Volume 7, Issue 4, Jul.-Aug., 2026 pp: 205-224 ISSN: 2584-2145 www.ijemh.com

Key Themes:

- Healthcare Operations Optimization
  - Queue theory for patient flow.
  - Emergency response systems.
- Strategic Health Policy Models
  - Governance quality:
    $G = Le/[C + B]$
- Digital Health Management
  - Blockchain for medical records.
  - AI-driven hospital decision systems.
- Sustainable Healthcare Systems
  - Cost-effective and scalable models for LMICs.

5. MEDICAL SCIENCES RESEARCH DIRECTIONS





Key Themes:

- Nanomedicine & Targeted Drug Delivery
  - Precision medicine using nanoparticles.
  - Controlled drug release systems.
- MHD-Based Biomedical Applications
  - Magnetic drug targeting and hyperthermia.
- AI in Diagnostics
  - Early disease detection using machine learning.
- Telemedicine & Remote Healthcare
  - IoT-enabled monitoring systems.
- Personalized Medicine
  - Integration of genomics + mathematical modeling.

INTERDISCIPLINARY RESEARCH OPPORTUNITIES

Integrated Models:

- Socio-Medical-Mathematical Frameworks (SMMF)
- AI + MHD + Nanotechnology in Healthcare
- Data-driven Public Health Systems

Emerging Topics:

- Smart Healthcare Ecosystems
- Predictive Policy Modeling
- Human-Centric AI in Medicine
- Sustainable Health Engineering

CONCLUSION

Future research must move toward integration rather than isolation:

- Combine mathematics + social science + medical science + management
- Focus on real-world problems (LMICs like India)
- Build data-driven, ethical, and scalable healthcare model

Citations and References:

1. Blakemore, R. (1975). Magnetotactic bacteria. Science, 190(4212), 377–379.
2. Griffiths, D. J. (1975). Negative-resistance effects in flow through collapsible tubes. Medical & Biological Engineering, 13(6), 785–790.
3. Gold, J. H., & Schuder, J. C. (1975). Electrolytic tank solution of electric field in biological media. IEEE Transactions on Biomedical Engineering, 22(6), 513–518.
4. Gupta, A. S., & Gupta, P. S. (1975). Dispersion of solute in MHD channel flow with chemical reactions. International Journal of Heat and Mass Transfer, 18(4), 531–535.

5. Taniguchi, N. (1974/1975). On the basic concept of nanotechnology. (Foundational terminology development).

Nanotechnology & Drug Delivery

6. Speiser, P. (1976). Nanoparticles in drug delivery systems (early concept of pharmaceutical nanotechnology).
7. Ringsdorf, H. (1975–1985). Structure–property relationships in polymeric drug carriers.
8. Szoka, F., & Papahadjopoulos, D. (1980). Liposome-based drug delivery systems.
9. Gregoriadis, G. (1976). Liposome technology in drug delivery.
10. Couvreur, P., & Vauthier, C. (1990). Polymeric nanoparticles in medicine.
11. Freitas, R. A. (1999). Nanomedicine, Vol. I: Basic Capabilities.
12. Sahoo, S. K., Parveen, S., & Panda, J. J. (2007). Nanotechnology in human healthcare. Nanomedicine, 3(1), 20–31.
13. Buzea, C., Pacheco, I., & Robbie, K. (2008). Nanomaterials and nanoparticles: Sources and toxicity.

MHD and Biofluid Mechanics

14. Raeder, J. (1975). MHD Power Generation. Springer.
15. Yamanishi, T. (1975). Liquid metal MHD power generation. Journal of the Society of Mechanical Engineers.
16. Cramer, K. R., & Pai, S. I. (1973/1975). Magnetofluid Dynamics for Engineers.
17. Shercliff, J. A. (1979). A Textbook of Magnetohydrodynamics.
18. Moreau, R. (1990). Magnetohydrodynamics.
19. Davidson, P. A. (2001). An Introduction to Magnetohydrodynamics.

Mathematical Modeling in Health & Engineering

20. Anderson, J. M., & Kim, S. W. (1970s–1980s). Biomaterials and drug delivery modeling.
21. Murray, J. D. (1989). Mathematical Biology.
22. Keener, J., & Sneyd, J. (1998). Mathematical Physiology.
23. Banks, H. T., & Tran, H. T. (2009). Mathematical and Experimental Modeling of Physical Systems.
24. Farsad, N., et al. (2014). Molecular communication and nano-biomedical systems.

Nanofluid and Heat Transfer Modeling

25. Choi, S. U. S. (1995). Enhancing thermal conductivity of fluids with nanoparticles.
26. Buongiorno, J. (2006). Convective transport in nanofluids.
27. Khan, W. A., & Pop, I. (2010). Nanofluid flow over stretching sheets.
28. Nadeem, S., & Lee, C. (2012). Boundary layer flow of nanofluid.

Health Engineering, Systems & Policy

29. Sahoo, S. K. et al. (2007). Applications of nanotechnology in healthcare.
30. Gebeshuber, I. C., & Majlis, B. Y. (2010). Biomimetic nanotechnology for global challenges.
31. WHO Reports (2000–2023). Health systems and primary healthcare frameworks.
32. World Bank (2017–2024). Health financing in LMICs.

Recent Interdisciplinary Developments

33. Noah, N., & Ndangili, P. (2021). Green nanotechnology for drug delivery.
34. Adeshara, J. V., Prajapati, M. B., Deheri, Gunamani M., & Patel, Rakesh Manilal H. (2020). Hydromagnetic squeeze film performance of conducting longitudinally rough elliptical plates. In Intelligent Manufacturing and Energy Sustainability (Smart Innovation, Systems and Technologies 169, pp. 199–208). Springer.
35. Adeshara, J. V., Patel, H. P., Deheri, Gunamani M., & Patel, Rakesh Manilal H. (2020). Theoretical study of hydromagnetic squeeze film in rough truncated conical plates with Kozeny–Carman porous structure. Proceedings on Engineering Sciences, 2(4), 389–400.
36. Vashi, Y. D., Patel, Rakesh Manilal H., & Deheri, Gunamani M. (2020). Neuringer–Rosensweig model based longitudinally rough porous circular stepped plates in the presence of couple stress. Acta Polytechnica, 60(3), 259–267.
37. Vadher, Pragna A., Deheri, Gunamani M., & Patel, Rakesh Manilal H. (2020). Effects of viscosity variation and velocity slip in hydromagnetic squeeze films between conducting porous circular plates. International Journal of Engineering Technology Research & Management, 4(8), 83–95.
38. Adeshara, J. V., Sorathiya, S. G., Patel, H. P., Deheri, Gunamani M., & Patel, Rakesh Manilal H. (2021). Mathematical modelling of circular plates with combined

effects of slip velocity and surface roughness on hydromagnetic squeeze film. GIS Science Journal, 8(3), 129–144.

39. Adeshara, J. V., Patel, H. P., Deheri, G. B., & Patel, Rakesh Manilal H. (2022). Performance of a hydromagnetic squeeze film on a rough circular step bearing: A comparison of different porous structures. Acta Polytechnica, 62(4), 409–417.
40. Deheri, Gunamani M., Vadher, Pragna A., Desai, L. S., & Patel, Rakesh Manilal H. (2022). Hydromagnetic squeeze film between conducting transversely rough curved circular plates lying along surfaces determined by exponential and hyperbolic functions. International Journal of Engineering Inventions, 11(12), 69–84.
41. Adeshara, J. V., Sorathiya, S. G., Patel, H. P., Deheri, Gunamani M., & Patel, Rakesh Manilal H. (2023). Surface roughness and deformation effects on the performance of hydromagnetic fluid based squeeze film on rough porous truncated conical plates. Journal of Mechanical Engineering Research and Developments, 46(1), 1–18.
42. Adeshara, J. V., Sorathiya, S. G., Patel, H. P., Deheri, Gunamani M., & Patel, Rakesh Manilal H. (2024). Influence of hydromagnetic squeeze film on a longitudinally rough circular step bearing: Comparison of porous structures. In Proceedings of the International Conference on Mathematical Science and Applications (ICMSA 2023) (pp. 73–180). CRC Press / Taylor & Francis.
43. Adeshara, J. V., Sorathiya, S. G., Patel, H. P., Deheri, Gunamani M., & Patel, Rakesh Manilal H. (2024). Performance of longitudinally rough circular step bearings with hydromagnetic squeeze films considering deformation and slip velocity. In Proceedings of the International Conference on Mathematical Science and Applications (ICMSA 2023) (pp. 73–180). CRC Press / Taylor & Francis.
44. Patel, H. P., Adeshara, J. V., Shekhawat, M. P., Deheri, Gunamani M., & Patel, Rakesh Manilal H. (2024). Mathematical analysis of bearing deformation and longitudinal roughness on hydromagnetic squeeze film performance with velocity slip on truncated conical plates. In Proceedings of the International Conference on Mathematical Science and Applications (ICMSA 2023) (pp. 73–180). CRC Press / Taylor & Francis.
45. Vadher, Pragna A., Deheri, Gunamani M., Mittal, A. S., Shekhawat, M. P., & Patel, Rakesh Manilal H. (2024). Hydromagnetic squeeze film between conducting transversely rough curved circular plates. In Proceedings of the International Conference on Mathematical Science and Applications (ICMSA 2023) (pp. 73–180). CRC Press / Taylor & Francis.
46. Vashi, Y. D., Patel, Rakesh Manilal H., & Deheri, Gunamani M. (2024). Effect of transverse surface roughness on conical bearings lubricated with ferrofluid in the presence of couple stresses. In Proceedings of the International Conference on Mathematical Science and Applications (ICMSA 2023) (pp. 73–180). CRC Press / Taylor & Francis.
47. Adeshara, J. V., Patel, H. P., Sorathiya, S. G., Deheri, Gunamani M., & Patel, Rakesh Manilal H. (2024). Mathematical modeling of hydromagnetic squeeze film in longitudinally rough conducting truncated conical plates considering slip velocity. Journal of Interdisciplinary and Multidisciplinary Research, 19(10), 39–57.
48. Patel, Rakesh Manilal H., Vadher, Pragna A., & Deheri, Gunamani M. (2024). Developing a computational model of axial oil flow from a porous rough hole. Scholarly Research Journal for Humanity Science & English Language, 12(65), 71–76.
49. Acharya, A. K., Chaudhari, H. D., Gadhavi, N. A., & Patel, Rakesh Manilal H. (2024). A review and socio-mathematical analysis of self-defense against infection: The impact of societal influences and awareness of danger. Alochana Journal, 13(10), 376–382.
50. Vadher, Pragna A., Deheri, Gunamani M., Valani, B. N., & Patel, Rakesh Manilal H. (2024). Behaviour of deformable elliptical plates with micropolar fluids. Journal of Technology, 12(12), 693–703.
51. Deheri, Gunamani M., Sorathiya, S. G., Adeshara, J. V., Patel, H. P., & Patel, Rakesh Manilal H. (2025). Effect of slip velocity on longitudinally rough hydromagnetic squeeze film between conducting rotating circular plates. Journal of Materials and Engineering, 3(2), 137–143.

52. Adeshara, J. V., Patel, H. P., Sorathiya, S. G., Deheri, Gunamani M., & Patel, Rakesh Manilal H. (2025). Effects of deformation and slip velocity with transverse roughness on the behaviour of a rectangular plate under hydromagnetic squeeze film lubrication. Journal of Sustainable Development Innovations, 2(1), 23–31.
53. Patel, Rakesh Manilal H., Vadher, Pragna A., Deheri, Gunamani M., & Valani, B. N. (2025). Ferrofluid-based tilted deformable rough porous pad bearing. GIS Journal of Science, 12(2), 348–359.
54. Acharya, A. K., Solanki, P. B., Gadhavi, N. A., Chaudhari, H. D., & Patel, Rakesh Manilal H. (2025). A socio-mathematical modeling approach to analyze the effectiveness of social protection interventions in reducing disease burden. OEIL Research Journal, 23(3), 1–20.
55. Vadher, Pragna A., Patel, J. R., Deheri, Gunamani M., Patel, P. R., & Patel, Rakesh Manilal H. (2025). Impact of viscosity variation on ferrofluid-based deformable porous rough long bearings. Technische Sicherheit (Technical Security), 25(3), 104–117.
56. Vadher, Pragna A., Perera, D. R., Kumar, S., Deheri, Gunamani M., & Patel, Rakesh Manilal H. (2025). A study of deformable rough surfaces on finite slider bearings. Technische Sicherheit (Technical Security), 25(4), 12–23.
57. Vadher, Pragna A., Deheri, Gunamani M., Mittal, A. S., Kumar, S., Chandulal, A., & Patel, Rakesh Manilal H. (2025). Hydromagnetic lubrication of a rough porous parabolic slider bearing with slip velocity. Aportes Journal, 16(5), 176–187.
58. Vadher, Pragna A., Perera, D. R., Kumar, S., Deheri, Gunamani M., & Patel, Rakesh Manilal H. (2025). Influence of magnetic fluids incorporating couple stresses, variable viscosity and velocity slip on lubrication performance of deformable rough finite journal bearings. International Journal of Engineering and Science Invention, 14(6), 1–9.
59. Vadher, Pragna A., Chandulal, A., Perera, D. R., Deheri, Gunamani M., Tandel, P. V., & Patel, Rakesh Manilal H. (2025). MHD micropolar fluid flow on porous triangular plates. International Journal for Research in Applied Science and Engineering Technology, 13(7), 1752–1759.
60. Vadher, Pragna A., Patel, Rakesh Manilal H., Perera, D. R., Deheri, Gunamani M., & Tandel, P. V. (2025). Piezo-viscous dependency and couple stresses on the performance of rough circular plates. International Journal of Engineering Research and Development, 10(3), 25–34.
61. Vadher, Pragna A., Deheri, Gunamani M., Perera, D. R., & Patel, Rakesh Manilal H. (2025). Deformable rough wide tapered land slider bearing. International Journal for Research in Applied Science and Engineering Technology, 13(7), 1021–1031.
62. Adeshara, J. V., Patel, H. P., Sorathiya, S. G., Vadher, Pragna A., Deheri, Gunamani M., & Patel, Rakesh Manilal H. (2025). Behaviour of rotating annular deformable rough plates under squeeze film conditions using the Rabinowitz fluid model. The International Journal of Engineering and Science, 14(9), 49–60.
63. Acharya, A. S., Vadher, Pragna A., Deheri, Gunamani M., & Patel, Rakesh Manilal H. (2025). Hydrodynamic deformable rough conical journal bearing. International Journal of Advanced Multidisciplinary Research and Studies, 5(5), 704–712.
64. Acharya, A. K., Chaudhari, H. D., Gadhavi, N. A., & Patel, Rakesh Manilal H. (2025). Political culture through the lens of mathematical models. Journal of Material Sciences & Applied Engineering, 4(5), 1–11.
65. Patel, Rakesh Manilal H., Vadher, Pragna A., Deheri, Gunamani M., Chaudhary, S., Perera, D. R., & Chandulal, A. (2025). Lubricant feeding environment and enhancement with reduced friction. Journal of Material Sciences & Applied Engineering, 4(5), 1–12.
66. Vadher, Pragna A., Deheri, Gunamani M., Perera, D. R., Chaudhary, S., & Patel, Rakesh Manilal H. (2025). Opportunities and risks in food safety and nutrition AI: A mathematical approach. Journal of Material Sciences & Applied Engineering, 4(5), 1–13.
67. Acharya, A. K., Solanki, P. B., Chaudhari, H. D., Gadhavi, N. A., & Patel, Rakesh Manilal H. (2025). A review on modeling based on political affiliation. International Journal of Computational Engineering Research, 15(9), 15–26.

68. Perera, D. R., Acharya, A. K., Chaudhari, H. D., Shah, B. S., Gadhavi, N. A., & Patel, Rakesh Manilal H. (2025). A review on education perspectives and research conceptions. Research Inventy: International Journal of Engineering and Science, 15(10), 98–117.
69. Kumar, N., Perera, D. R., Vadher, Pragna A., Deheri, Gunamani M., & Patel, Rakesh Manilal H. (2025). For roughly a hundred generations, wealth remained relatively equal after the Neolithic transition. Research Inventy: International Journal of Engineering and Science, 15(10), 70–84.
70. Perera, D. R., & Patel, Rakesh Manilal H. (2025). Integration of mathematical modeling and professional education: A framework for high-quality development in vocational institutions. International Journal of Novel Trends and Innovation, 3(10), a113–a126.
71. Solanki, P. K. B., Perera, D. R., Acharya, A. K., Shah, B. S., Gadhavi, N. A., Chaudhari, H. D., & Patel, Rakesh Manilal H. (2025). Mathematical modeling in management: Insights from social and behavioral sciences. International Journal of Novel Trends and Innovation, 3(11), a136–a149.
72. Vadher, Pragna A., Deheri, Gunamani M., & Patel, Rakesh Manilal H. (2025). Tribological assessment of porous Kozeny–Carman short bearings under viscosity variation and elastic roughness deformation. Journal of Oil, Petroleum Technology and Natural Gas, 115, 1–6.
73. Darji, D. R., Perera, D. R., & Patel, Rakesh Manilal H. (2025). India's pluralism and global ethics: Ethical translation and inter-civilizational dialogue over monolithic moral traditions. Journal of Material Sciences & Applied Engineering, 4(6), 1–10.
74. Patel, Rakesh Manilal H., & Perera, Dhinesha R. (2025). Review of smart governance through social, managerial and quantitative modeling approaches. International Journal of Advanced Multidisciplinary Research and Studies, 6(1), 11–17. E-ISSN: 2583-049X. Available at: https://www.multiresearchjournal.com/archives-list/id-2026.6.1
75. Patel, Rakesh Manilal H. H., Perera, Dhinesha R., Gadhavi, N. A., Acharya, A. K., & Chaudhari, H. D. (2026). Emerging perspectives in modeling and simulation in mathematical sociology. International Journal of Recent Development in Engineering and Technology (IJRDET), 15(1), 370–381. ISSN: 2347-6435 (Online).
76. Patel, Rakesh Manilal H., & Perera, Dhinesha R. (2026). A decision-driven optimization framework for surface roughness control in micro-milling of NiTi shape memory alloys using a modified differential evolution algorithm. International Journal of Recent Development in Engineering and Technology (IJRDET), 15(1), 382–392. ISSN: 2347-6435 (Online).

DECLARATIONS

Author Contributions All authors contributed significantly to the conception, design, analysis, and writing of the manuscript. The work was collaboratively developed, critically reviewed, and approved by all authors, who accept full responsibility for its content and integrity.

Funding Statement This research received no external funding and was conducted independently by the authors.

Conflict of Interest The authors declare no conflicts of interest.

Data Availability Data and materials are available from the corresponding author upon reasonable request.

Ethics Approval & Consent Not applicable. This study does not involve human or animal subjects.

Ethics Statement The research was conducted in accordance with accepted academic and ethical standards, ensuring integrity and transparency.

AI Assistance Disclosure AI tools were used only for language refinement and formatting. All intellectual content is the original work of the authors.

ACKNOWLEDGEMENT The authors thank their institutions and colleagues for academic support and constructive feedback. They also acknowledge the global research community and open-access resources that contributed to this work.