



INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI  
SHORT ABSTRACT OF THESIS

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This thesis develops and analyzes a series of multi-strain mathematical models to investigate the transmission dynamics and control of Human Immunodeficiency Virus (HIV) in a community, with particular focus on the emergence of drug resistance, the role of treatment availability, and the impact of adherence to antiretroviral therapy (ART). Starting with a basic two-strain model in the absence of treatment, we establish that competitive exclusion prevents the coexistence of drug-sensitive and drug-resistant strains when only natural transmission pathways are considered. Extending this framework to include treatment availability and adherence, we demonstrate that coexistence becomes possible under certain conditions, and that treatment-related factors critically influence long-term epidemic outcomes. The models reveal the occurrence of transcritical and Hopf bifurcations, leading to periodic epidemic behavior within specific parameter ranges, and highlight the crucial role of transmission rates, disease-induced mortality, and treatment adherence in shaping epidemic trajectories. Building on this foundation, we further incorporate AIDS progression, diagnosis status, and treatment switching from first-line to second-line therapy. Analytical results establish conditions for the persistence or elimination of different strains, and sensitivity analyses identify key drivers of both short- and long-term dynamics, with parameter interactions exerting strong influence on epidemic outcomes. Optimal control theory is applied to design and compare multiple intervention strategies, including diagnosis-focused, treatment-focused, adherence-focused, balanced, and dynamic approaches. A dynamic optimization framework is proposed that achieves the UNAIDS 95-95-95 targets through efficient and adaptive allocation of healthcare resources. Cost-effectiveness analysis, adjoint-based sensitivity methods, and Shapley value analysis are employed to assess the economic viability of interventions and to quantify the relative contribution of each control measure. Overall, the results emphasize that while expanding treatment coverage remains important, the long-term success of HIV epidemic control depends critically on adherence-focused strategies and timely switching to second-line therapies. The models not only provide theoretical insights into the mechanisms governing HIV dynamics but also deliver practical guidance for policy-makers in designing efficient, sustainable, and cost-effective intervention programs.