NEAR EAST UNIVERSITY

KOCAELİ UNIVERSITY

INTERNATIONAL COLLABORATION IN THE MEASUREMENT AND ANALYSIS OF HIV DATA: GLOBAL, TÜRKİYE, AND CYPRUS PERSPECTIVES

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Introduction and International Collaboration Framework

This report has been prepared within the framework of an international academic collaboration between Near East University and its partner institution, with the aim of contributing to the gathering, measurement, and analysis of data relevant to the United Nations Sustainable Development Goals, particularly SDG 3 (Good Health and Well-being).

The collaboration focuses on the joint use, harmonisation, and modelling of internationally recognised epidemiological and demographic datasets related to HIV, including data obtained from the World Health Organization (WHO), UNAIDS, the European Centre for Disease Prevention and Control (ECDC), and national public health authorities. Through this partnership, the institutions jointly contributed to the analytical design, parameter selection, and interpretation of outputs generated by mathematical modelling approaches.

By integrating global, national (Türkiye), and regional (Cyprus) datasets within a shared modelling framework, the collaboration supports the measurement and monitoring of progress related to SDG 3.3, which aims to end the epidemics of AIDS and other communicable diseases. The outcomes of this work provide evidence-based insights that can inform public health monitoring, future projections, and policy-oriented decision-making at international and national levels.

The modelling framework supports ongoing monitoring of HIV-related indicators, enabling comparative evaluation of trends and progress across different geographical contexts over time

The collaboration involved joint analytical design, shared interpretation of epidemiological indicators, and comparative assessment of HIV trends across global, national, and regional contexts.

The Structure of a Mathematical Model

Mathematical modelling in health sciences is a quantitative approach used to describe, analyze, and predict the dynamics of diseases including infectious diseases within a population. By converting real-life problems and biological processes of infectious diseases into mathematical equations. These models enable researchers to understand how pathogens spread, to identify key transmission drivers, and to evaluate the potential impact of public health interventions. They provide a structured framework through which future scenarios can be simulated, policy decisions can be supported, and control strategies can be optimized.

A central concept in infectious disease modelling is the basic reproduction number, denoted as R_0 (R-naught). R_0 represents the average number of infections generated by a single infected

individual in a completely susceptible population. If $R_0 \geq 1$, the infection is expected to persist and spread, whereas $R_0 < 1$ indicates that transmission will eventually decline and the disease will fade out. Therefore, R_0 serves as a critical threshold parameter for assessing epidemic potential and for determining the level of intervention required to achieve disease control or elimination.

Human Immunodeficiency Virus (HIV) remains to be a major global public health challenge, affecting millions of individuals, worldwide. The virus primarily targets the immune system, leading to progressive immune suppression and, if without any treatment, it develops as Acquired Immunodeficiency Syndrome (AIDS). Despite significant advances in antiretroviral therapy (ART) that have improved life expectancy and reduced transmission, HIV continues to pose complex epidemiological and clinical challenges. Understanding the dynamics of HIV transmission and disease progression is therefore essential and valuable; and mathematical modelling provides a powerful framework to analyze these dynamics, to evaluate intervention strategies, and to inform public health decision-making.

In this report, the mathematical model, illustrated in Figure 1, is developed in order to understand the dynamics of HIV transmission. In this study, demographic, epidemiological, and treatment-related data is integrated to the model for estimating HIV transmission dynamics and for assessing both the current situation and future projections at the global level, in Türkiye, and in Cyprus.

$$\frac{dS}{dt} = \Lambda - \lambda S - \mu S,$$

$$\frac{dI_u}{dt} = \lambda S - \phi I_u - \mu I_u - \sigma I_u,$$

$$\frac{dI_d}{dt} = \phi I_u - \rho I_d - \mu I_d - \sigma I_d,$$

$$\frac{dT}{dt} = \rho I_d - \gamma T - \mu T,$$

$$\frac{dA}{dt} = \sigma(I_u + I_d) + \gamma T - (\mu + \delta_A)A,$$

$$\lambda = \frac{\beta_u I_u + \beta_d I_d + \beta_t T}{N}$$

Figure 1. The designed mathematical model

Current Situation of HIV Cases at the Global Level Using Mathematical Modeling

In this section, the current global situation of HIV is evaluated using the designed mathematical model. The model uses parameter values taken from the WHO's 2024 statistical data, as presented in Table 1, which were incorporated into the model.

Table 1. Model Parameters and Values used for the Global Analysis

Variable/Parameter	Description	Value
S	Susceptible individuals	~8.06 billion
I_u	Undiagnosed HIV individuals	~4.6 million
I_d	HIV Diagnosed individuals (treatment naive)	~3.8 million
T	HIV Diagnosed Individuals taking ART Treatment	~31.6 million
A	Individuals with AIDS	~1.55 million
μ	Natural Death Rate	0.008
Λ	Recruitment Number	~1.2×10^8
σ	Rate of progression to AIDS	0.1
ρ	Treatment initiation rate	0.7
α	AIDS-related rate	0.016

[1-4]

Using the data incorporated into the designed mathematical model, the R_0 of the global HIV epidemic was estimated to be 1.13 (Figure 2). This value indicates sustained transmission at the global level and is consistent with the pandemic character of HIV, as each infected individual is expected, on average, to infect one susceptible person.

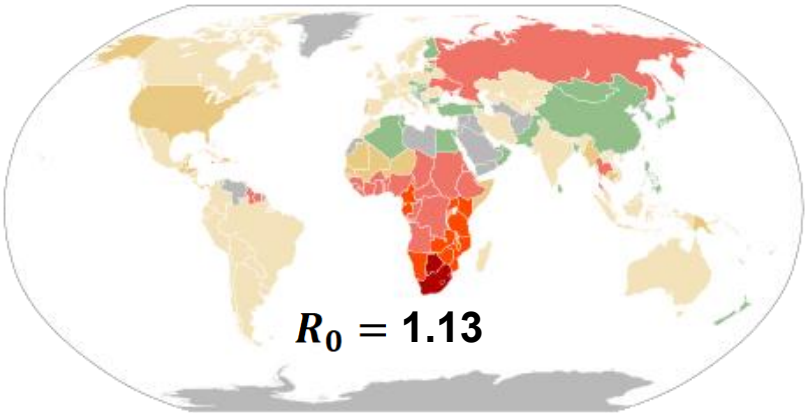

Figure 2. Calculation of the Global HIV Basic Reproduction Number R_0 = 1.13

Future Predictions of HIV Cases at the Global Level Using Mathematical Modeling

In addition to assessing the current situation, a 15-year simulation was performed using the designed mathematical model. Using the estimated number of new HIV infections worldwide reported by the WHO, which was reported as approximately 1.3 million in 2024, the model projects a gradual decline in global HIV transmission over the coming years. The projected reduction in the number of people living with HIV over the next 15 years is illustrated in Figure 3.

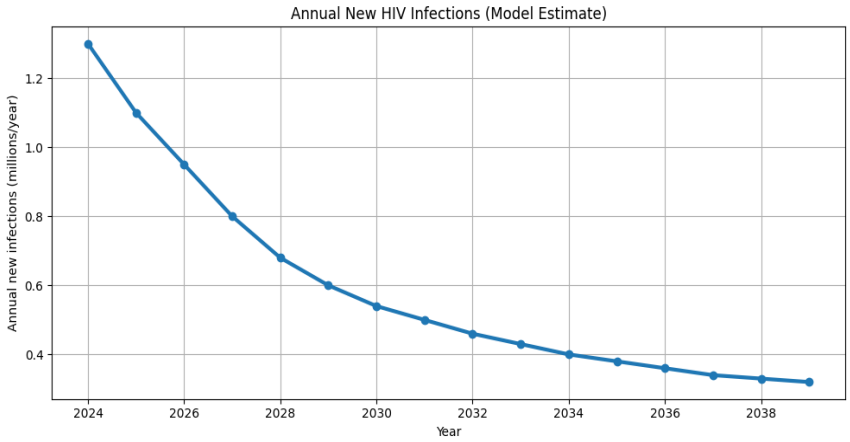

Figure 3. Fifteen-Year Future Predictions of the Global Population Living with HIV

Current Situation of HIV Cases in Türkiye Using Mathematical Modeling

In this section, the current situation of HIV in Türkiye is assessed using the designed mathematical model. The model incorporates parameter values obtained from the Ministry of Health of the Republic of Türkiye, based on HIV data reported between 1985 and August

2025, as well as demographic data from the Turkish Statistical Institute (TÜİK), as presented in Table 2. By integrating these national epidemiological and demographic inputs, the model provides an evidence-based evaluation of HIV transmission dynamics and the current epidemiological status in Türkiye.

Table 2. Model Parameters and Values used for the Türkiye Analysis

Variable/Parameter	Description	Value
S	Susceptible individuals	~85.5 million
I_u	Undiagnosed HIV individuals	~47706
I_d	HIV Diagnosed individuals (treatment naive)	~8250
T	HIV Diagnosed Individuals taking ART Treatment	~37585
A	Individuals with AIDS	~3542
μ	Natural Death Rate	0.012
Λ	Recruitment Number	~1092
σ	Rate of progression to AIDS	0.1
ρ	Treatment initiation rate	0.513
α	AIDS-related rate	0.015

[5-8]

Based on the parameters integrated into the designed mathematical model, the R_0 for HIV in Türkiye was determined to be 1.05 (Figure 4). This outcome indicates that HIV transmission continues to be maintained within the population and that the infection retains its epidemic characteristics at the national level. An R_0 value exceeding one signifies that an individual living with HIV is, on average, capable of passing the virus to at least one other susceptible person, thereby enabling the infection to persist over time.

Figure 4. Estimated R_0 Value 1.05 for the HIV Epidemic in Türkiye

Future Predictions of HIV Cases in Türkiye Using Mathematical Modeling

In extending the analysis of Türkiye's HIV burden, a 15-year simulation was carried out using the designed model. The results indicate a slow but steady increase in the number of new HIV cases over the projected period (Figure 5). This pattern differs from the global trend and is largely attributed to insufficient diagnosis rates in Türkiye. Inadequate early detection leads to prolonged periods of unrecognized infection, allowing individuals who are unaware of their status to continue transmitting the virus, thereby sustaining the epidemic.

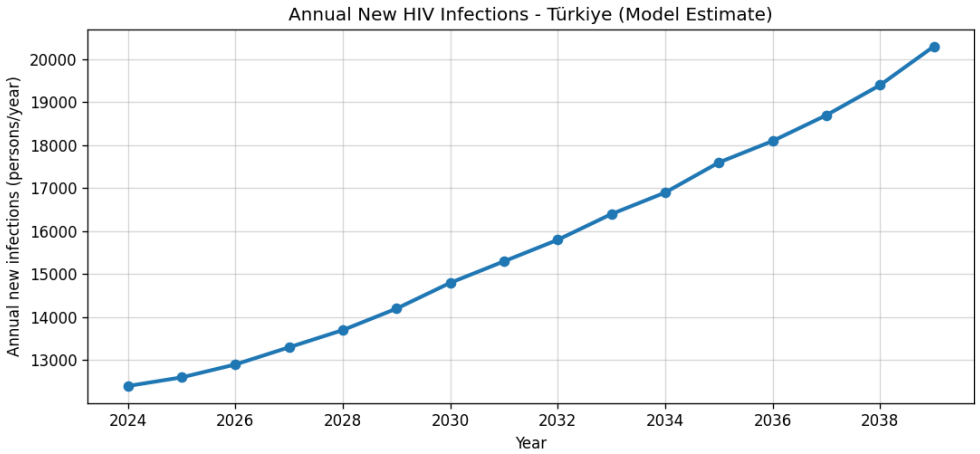

Figure 5. Fifteen-Year Projections of the Population Living with HIV in Türkiye

Current Situation of HIV Cases in Cyprus Using Mathematical Modeling

The current situation of HIV in Cyprus is also evaluated using the designed mathematical model. The model incorporates parameter values obtained from internationally recognized surveillance sources, including UNAIDS, WHO, and the European Centre for Disease Prevention and Control (ECDC), which provide HIV data for Cyprus covering the period from 1986 to 2022 as illustrated in Table 3. These epidemiological data, together with relevant demographic indicators, were integrated into the model as presented in Table 3. By combining these national and international data inputs, the model delivers a robust, data-driven assessment of HIV transmission dynamics and the current epidemiological status of HIV in Cyprus.

Table 3. Model Parameters and Values used for the Cyprus Analysis

Variable/Parameter	Description	Value
S	Susceptible individuals	~1.3 million
I_u	Undiagnosed HIV individuals	~432
I_d	HIV Diagnosed individuals (treatment naive)	~241
T	HIV Diagnosed Individuals taking ART Treatment	~1485
A	Individuals with AIDS	~73
μ	Natural Death Rate	0.008
Λ	Recruitment Number	1524
σ	Rate of progression to AIDS	0.1
ρ	Treatment initiation rate	0.66
α	AIDS-related rate	0.003

[9]

Using the parameter set incorporated into the mathematical model, R_0 for HIV in Cyprus was estimated to be 0.778 (Figure 6). An R_0 value below one indicates that HIV transmission cannot be sustained under current epidemiological conditions and that the infection does not display an epidemic pattern at the population level. In practical terms, each individual living with HIV is expected, on average, to transmit the virus to fewer than one susceptible person, which over time results in a gradual reduction in onward transmission. This outcome aligns with the model's projections and demonstrates that, in its current state, the HIV situation in Cyprus remains below the threshold required for continuous community-level spread.

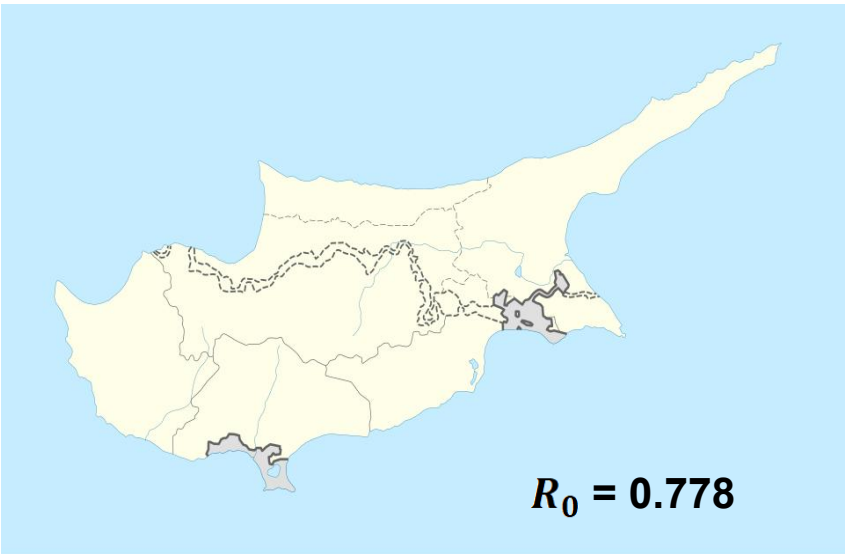

Figure 6. Calculated R_0 Value of 0.778 for the HIV Situation in Cyprus

Future Predictions of HIV Cases in Cyprus Using Mathematical Modeling

For the future prediction analysis in Cyprus, the model was simulated over a 15-year period. The results indicate that HIV remains under control and at a low-level endemic state in the country (Figure 7). However, a decline in diagnosis rates or reduced access to ART could lead to an increase in new infections, underscoring the importance of maintaining strong surveillance and treatment coverage.

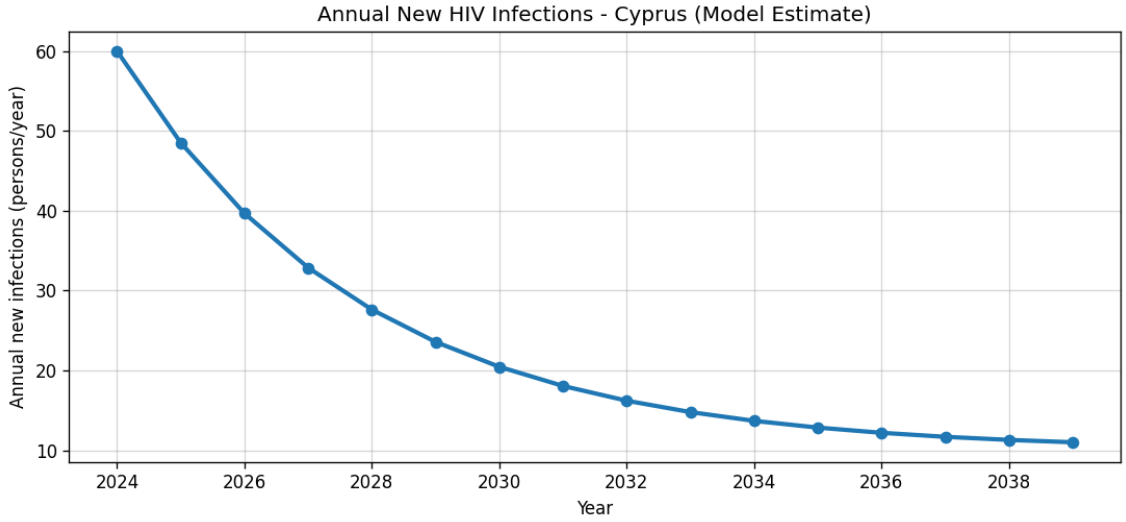

Figure 7. Fifteen-Year Projections of the Population Living with HIV in Cyprus

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