# The impact of vaccination on the spread of varicella in Hungary

HU-MATHS-IN
Hungarian Service Network for Mathematics in Industry and Innovations

## CHALLENGES

**Health, demographic change and wellbeing**

**The Industrial Problem**
Varicella Zoster Virus (VZV) causes chickenpox typically in children, and herpes zoster in adults (reactivation of the latent virus). Infections can be effectively prevented by a vaccine. In Hungary, varicella vaccination into the mandatory schedule incorporated in 2019.

Public health, epidemiology

*Research group*

**Mathematical Epidemiology**

Epidelay Group
Bolyai Institute

Mathematical study and computer simulations in mathematical epidemiology. Delay and hybrid models, networks.

*Company*

**Hungarian National Centerof Public Health**

NNK NEMZETI NÉPEGÉSZSÉGÜGYI KÖZPONT

Hungarian national headquarter of public health.

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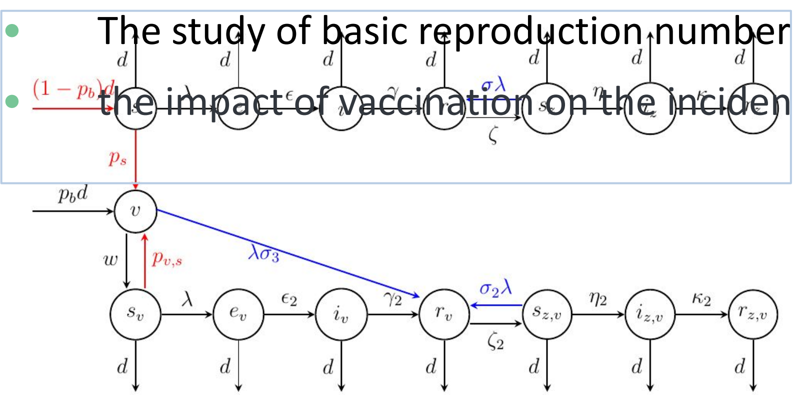
## Challenges & Goals

- Build new models and incorporate vaccination strategies into them according to the Hungarian specialties including seasonality.
- Parameter fitting and sensitivity analysis (LHS/PRCC method) of system parameters
- The study of basic reproduction number a
- the impact of vaccination on the incidenc




$$
\begin{aligned}
s' &= (1-p_b)\,d - p_s s - ds - \lambda s,\\
e' &= \lambda s - e(d+\epsilon),\\
i' &= e\epsilon - i(\gamma+d),\\
r' &= -r(d+\zeta) + \gamma i + \lambda\sigma s_z,\\
s_z' &= -(d+\eta)s_z - \lambda\sigma s_z + \zeta r,\\
i_z' &= \eta s_z - i_z(d+\kappa),\\
r_z' &= \kappa z - d r_z,\\
v' &= p_b d + p_s s + p_{v,s} s_v - \lambda\sigma_3 v - wv,
\end{aligned}
$$

$$\lambda = \beta(i + \nu\, i_z + \rho i_v + \nu i_{z,v})$$

$$
\begin{aligned}
s_v' &= -p_{v,s} s_v - d s_v - \lambda s_v + wv,\\
e_v' &= \lambda s_v - (d+\epsilon_2)\, e_v,\\
i_v' &= \epsilon_2 e_v - i_v\,(\gamma_2 + d),\\
r_v' &= \lambda\sigma_2 s_{z,v} - (d+\zeta_2)\, r_v + \lambda\sigma_3 v + \gamma_2 i_v\\
s_{z,v}' &= -(d+\eta_2)\, s_{z,v} - \lambda\sigma_2 s_{z,v} + \zeta_2 r_v,\\
z_v' &= \eta_2 s_{z,v} - (d+\kappa_2)\, z_v,\\
r_{z,v}' &= \kappa_2 z_v - d r_{z,v}
\end{aligned}
$$

*The transmission scheme and the compartmental equation. Framed part is the model with no vaccination used in parameter estimations.*
*λ: force of infection, proportional to the contacts of susceptible and infectious individuals.*

# Vaccination strategies for varicella in Hungary

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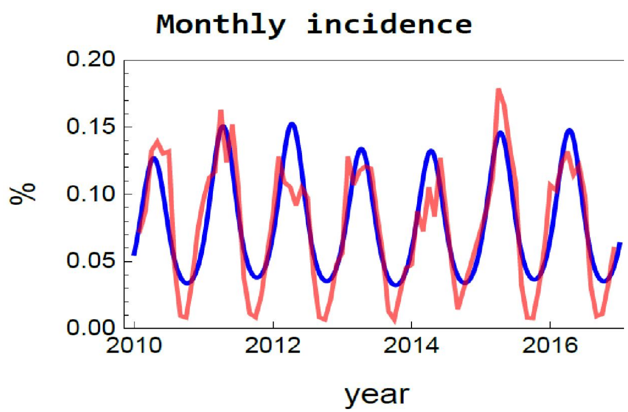
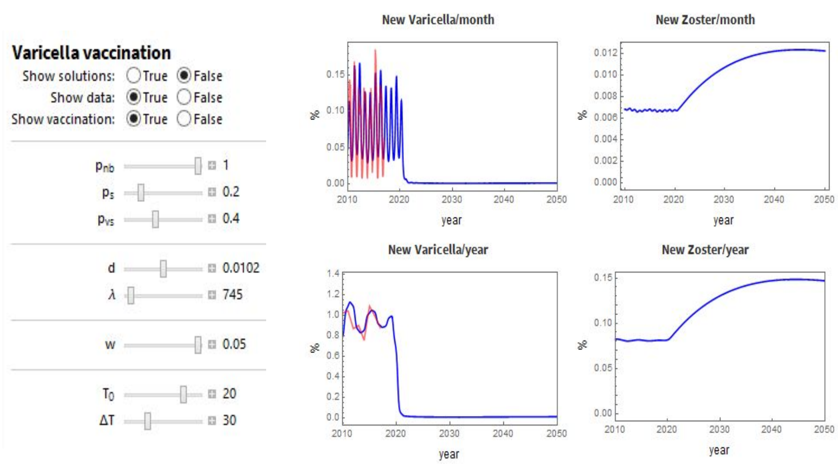
## Mathematical and computational methods and techniques applied

- Construction of a state-of-the-art transmission model with no vaccination that is the most realistic and providing the best fitting to the reported incidence data in Hungary.
- Sensitivity analysis on dependence of basic reproduction number on system parameters.
- Study of the dependence of basic reproduction number on underreporting.
- Combination of analytical (compartmental models, nonlinear impulsive systems, next-generation operator, spectral analysis), statistical, numerical, computational (e.g., fitting, sensitivity, optimization …), as well as epidemiological and simulation tools.




*Fitting the sesonal model*




*Dynamic simulations on the model: an effective vaccination case*

# Vaccination strategies for varicella in Hungary

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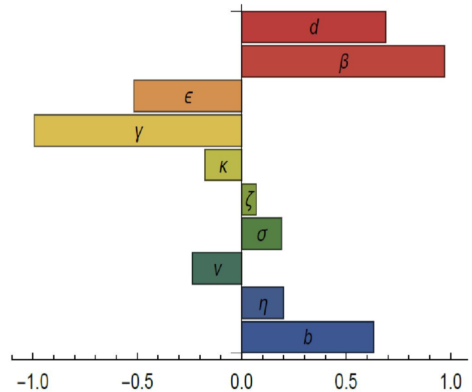
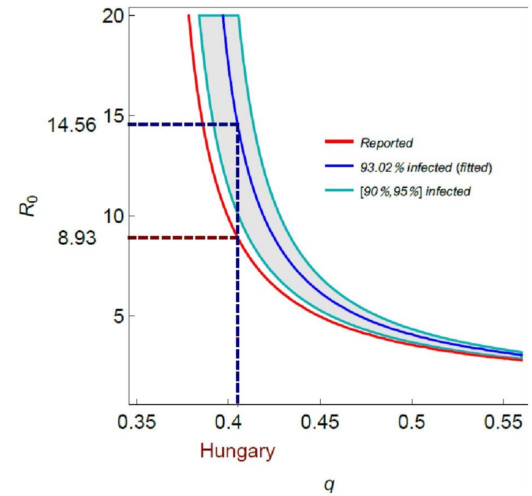
## Results & Benefits to the company

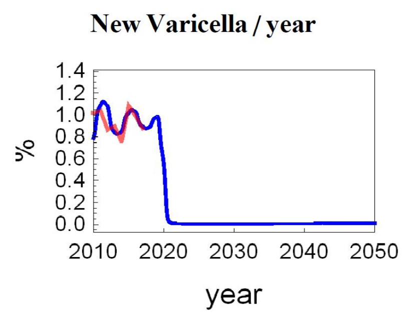
- General scheme model of Varicella transmission
- Scientific results on the spread of Varicella-Zoster Virus with and without vaccination.
- Finding key factors to decrease the basic and control reproduction numbers.
- Emphasizing the importance of underreporting.
- Comparing the effect of different vaccination strategies.
- The results help to make scientific, evidence-based decisions in optimizing the routine varicella vaccinations in Hungary, affecting the whole population and billions of HUFs.

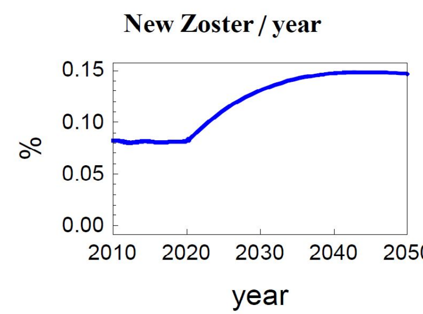



*Seasonal case: sensitivity (max. PRCC values, t∈[0,5])*




*Relation between underreporting ratio and $R_0$*




*An effective comprehensive vaccination*

**The National Center of Public Health receives dynamic modeling tools and analysis of vaccination strategies.**