Járványok matematikai modellezése és ennek szerepe a döntéselőkészítésben

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COVID-19 Mathematical Modelling and
Epidemiological Analysis Task Force

Hungarian COVID-19 Mathematical Modelling and Epidemiological Analysis Task Force

MATHEMATICAL MODELLING AND SIMULATIONS

- Social Mixing Patterns
- Transmission Dynamics
- Statistical Analysis
- Control Theory
- Agent Based Modeling

EPIDEMIOLOGICAL SURVEILLANCE AND ANALYSIS

DATA IN ACTION BIG HEALTH DATA

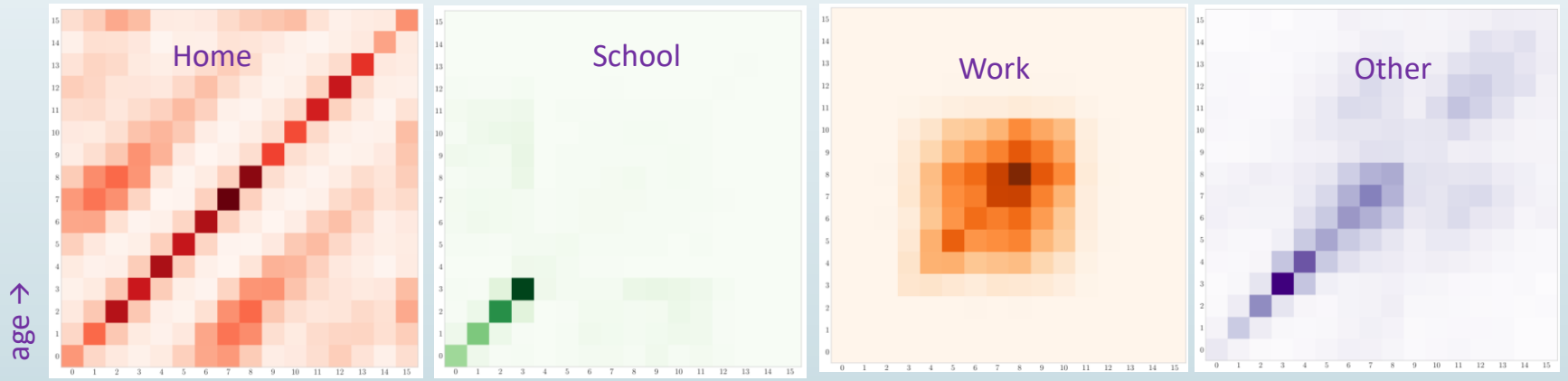
ENABLERS

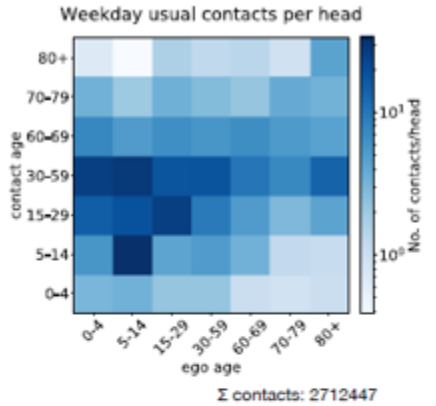
COLLABORATIONS WITH OTHER RESEARCHERS: VIROLOGY, IMMUNOLOGY etc.

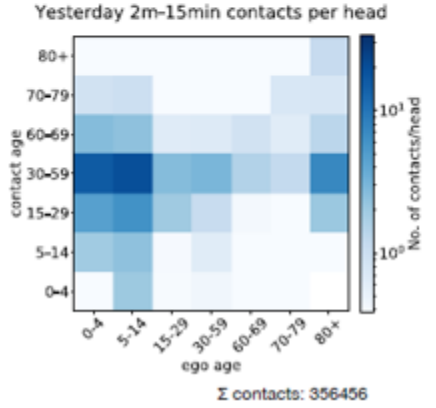
Multidisciplinary expert group,
representing many institution across the country,
Integrating various skills, competencies and fields of expertise:
mathematics, epidemiology, medicine, data science, computer science, network science, system biology, biostatistics, health management, computational social sciences

Core group: 10-15 people
Overall: 55 participating researchers
Goal: provide reliable information and up-to date analysis to support decision making

Innovative research: tracking social contact dynamics

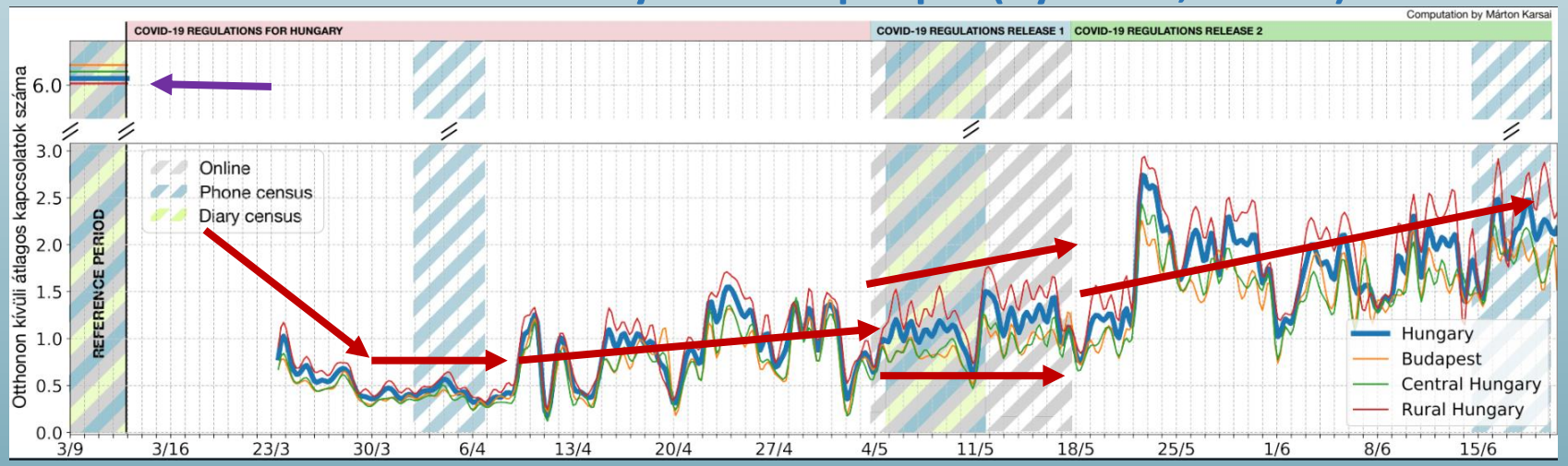






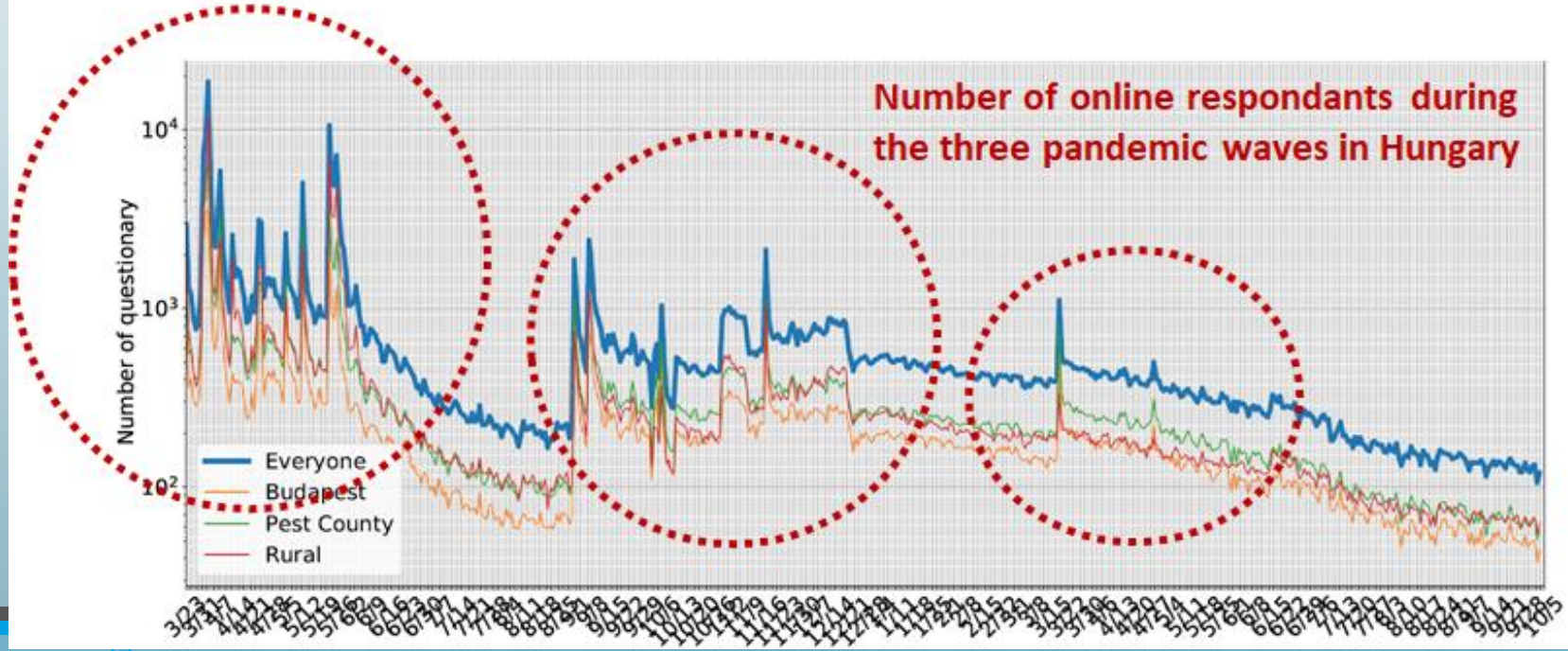
MASZK, Hungary: online questionnaire

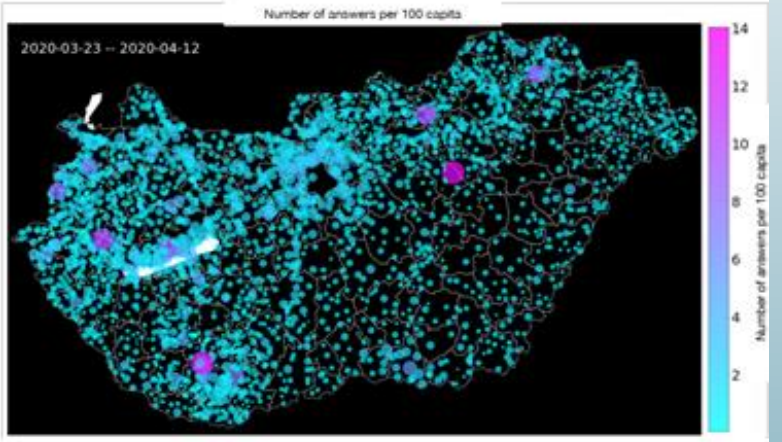
answered by 250 000 people (dynamic, trends)



covid.sed.hu

- Co-Mix: The **CoMix survey** in Hungary has had 9 waves of data collection covering the period between 25 May 2021 and 14 September 2021.
- MASZK – Magyar Adatszolgáltató Kérdőív (http://koronaviruskutatas.sed.hu), University of Szeged
  - Started from March 23, 2020, still ongoing
  - **online questionnaire** (http://covid.sed.hu), and mobile application
  - collected data from more than 250 000 people (possibly the largest number ever)
  - to correct non-representativity, complemented with **monthly phone surveys** on a representative sample of 1000-1500 people, 17 waves so far



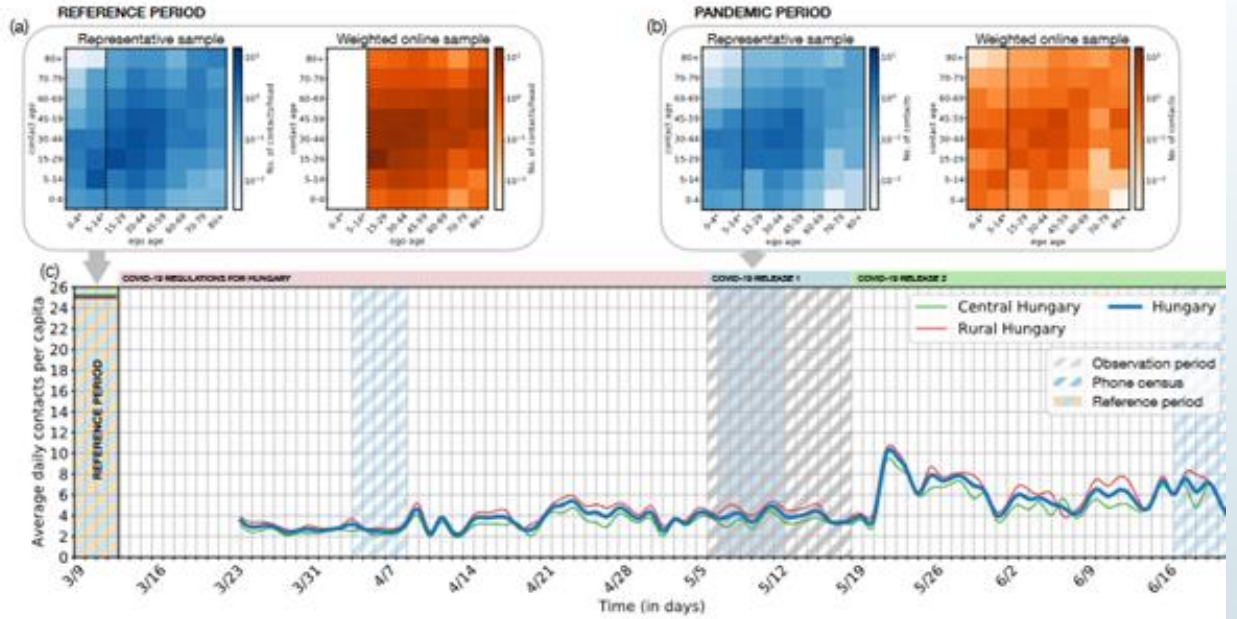


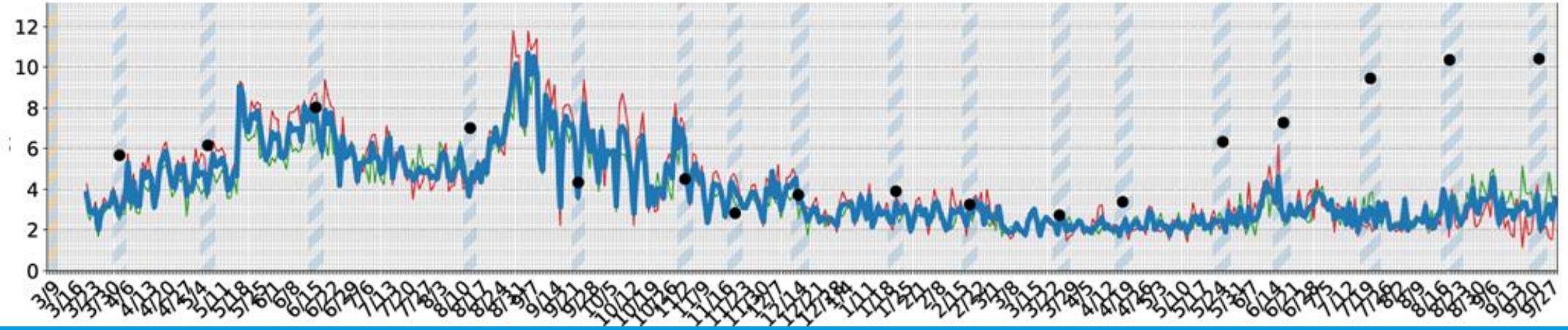
Collected data on:

- Social mixing patterns in detailed breakdown
- COVID-19 history
- Testing experiences
- Mobility
- International travel
- Mask compliance
- Vaccination attitudes by vaccine types

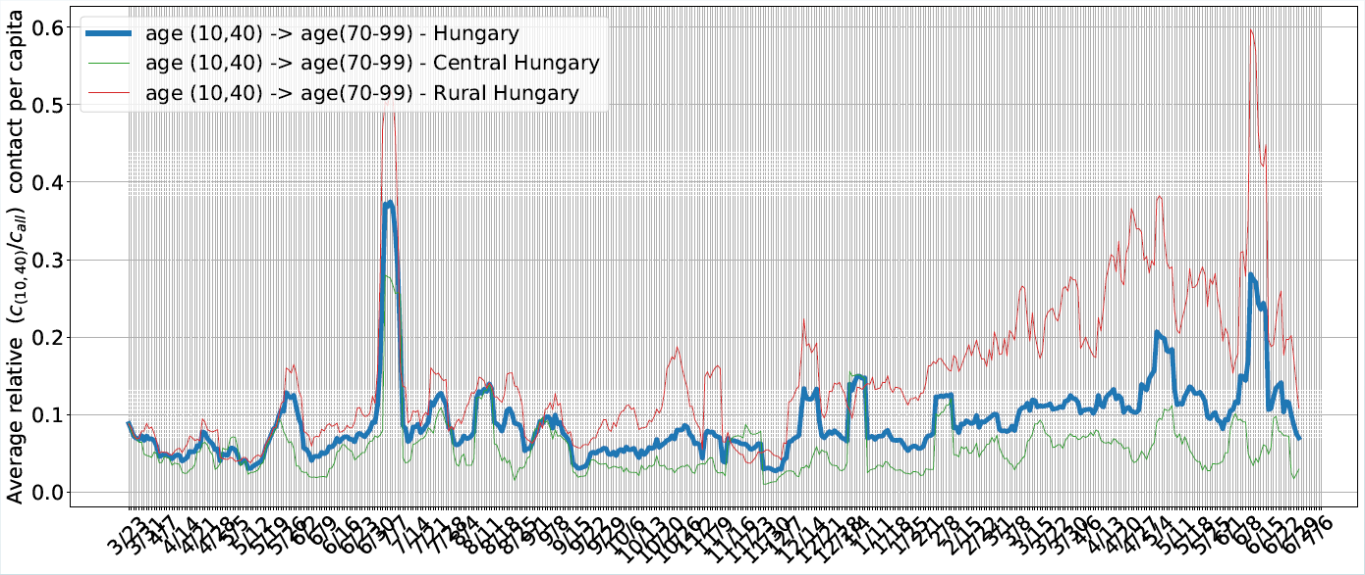
(extremely interesting due to Hungary's special vaccine portfolio)

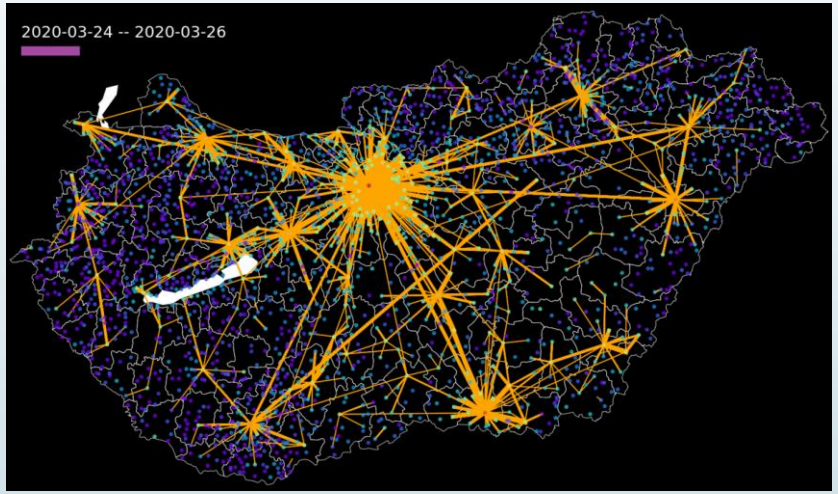
- Trust
- Conspiracy theories
- etc.





Examples: critical contacts, mobility, vaccine attitudes



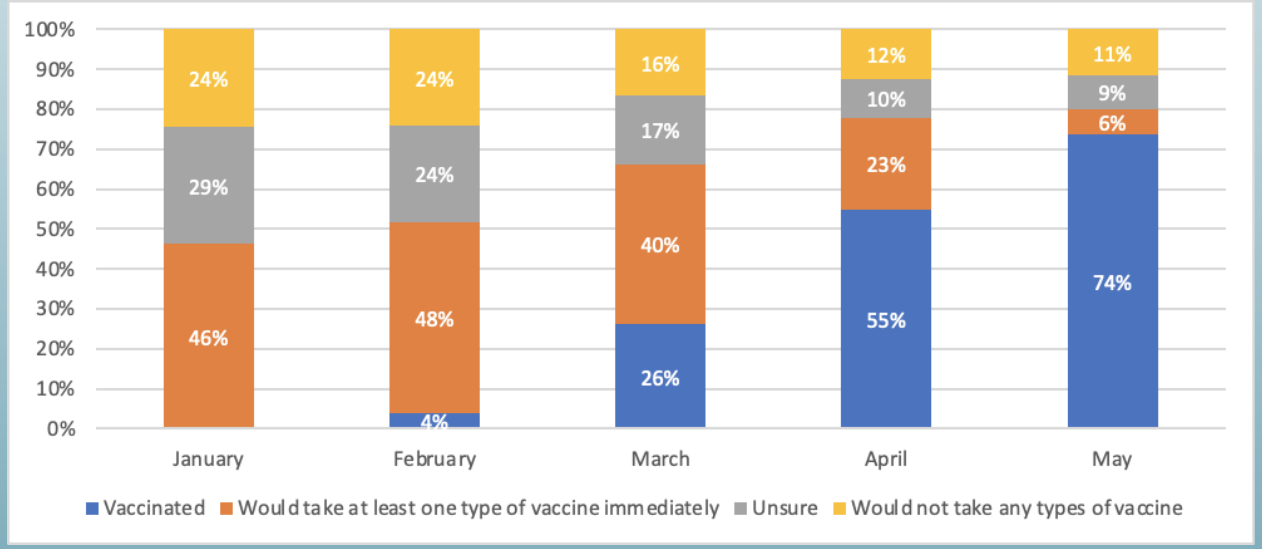


Online questionnaire + monthly representative surveys

Lots of new features incorporated:

- Travels
- Mask compliance
- Vaccination attitudes
- Who people trust
- Prevalence of false information etc.

Huge dataset collected, many ongoing analysis



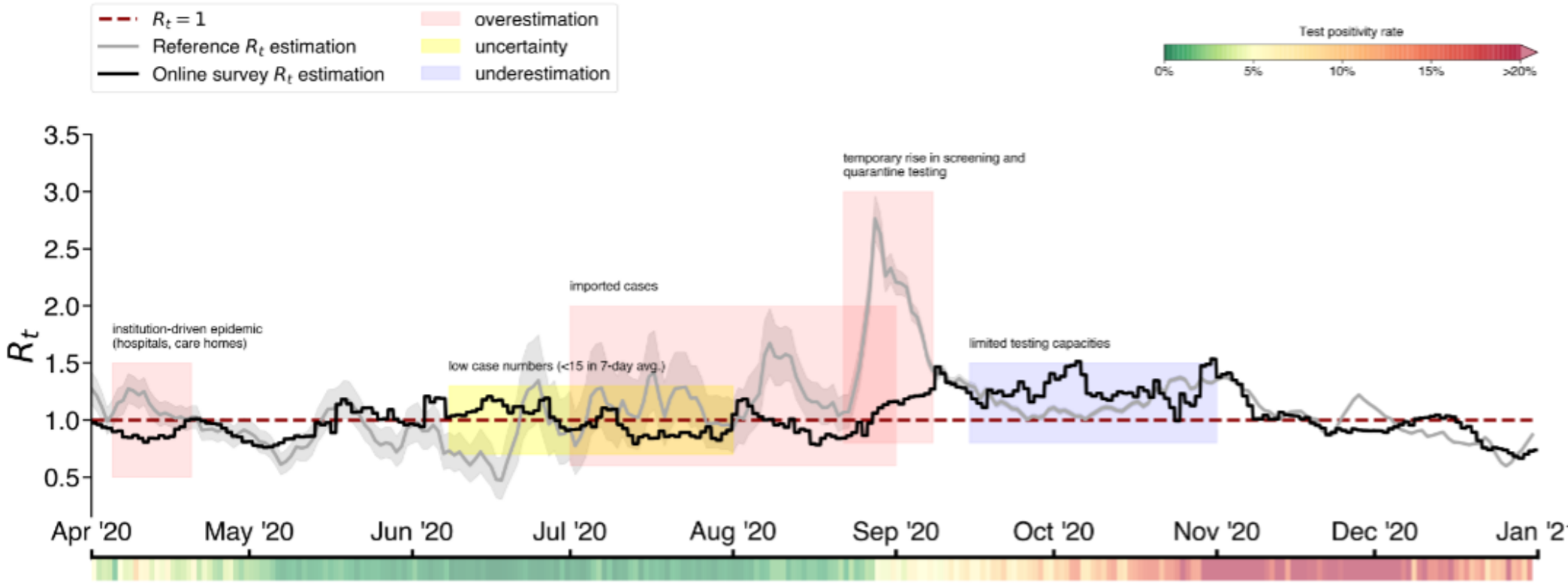
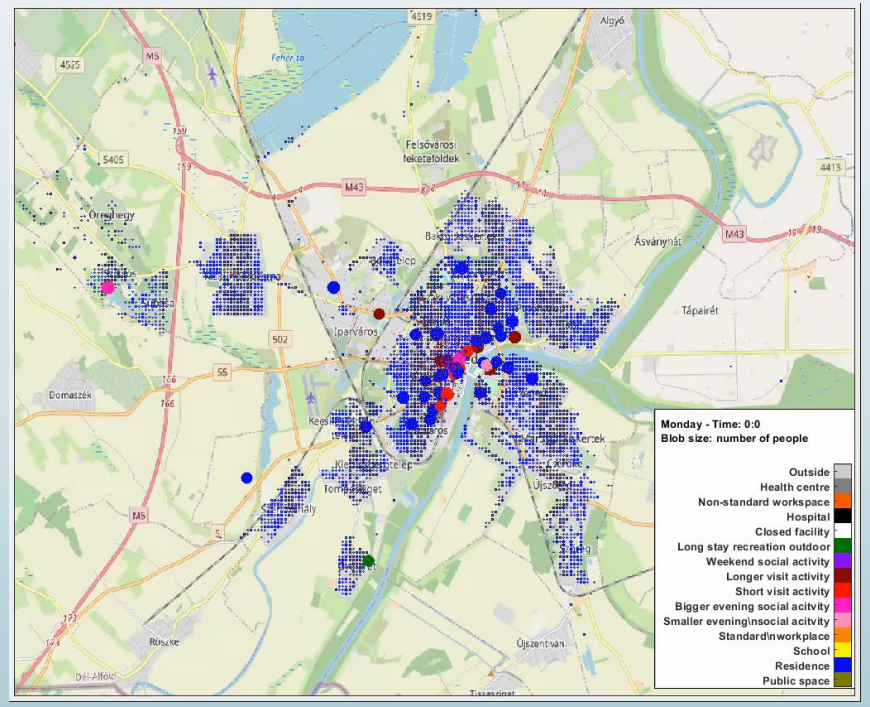
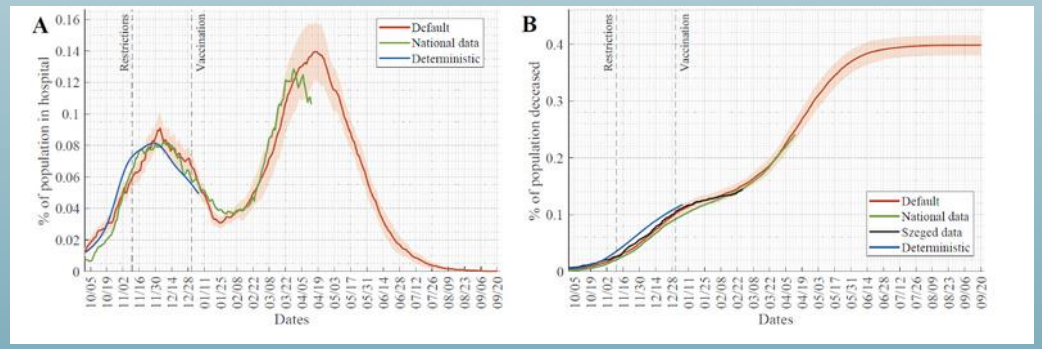


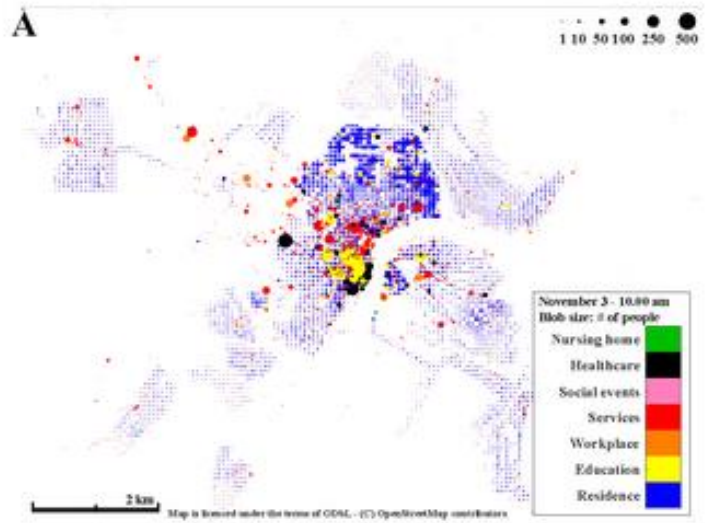
Figure 3. Effective reproduction rates between 1st April 2020 and 31st December 2020 in Hungary estimated from the daily contact matrices of the online survey (black), and from the case numbers using the Cori method (grey) [cite Ferenci]. The grey area indicates the statistical confidence interval of the reference R_t estimation. Red dashed line shows the $R_t = 1$ critical reproduction rate. Colored stripe below the horizontal axis shows the test positivity rate as a percentage of positive tests of all tests taken in the country on the given day. Annotated boxes show periods where methods based on case numbers either overestimate (red) or underestimate (blue) the reproduction rate, and where the method has a lot of uncertainty due to very low case numbers (yellow).

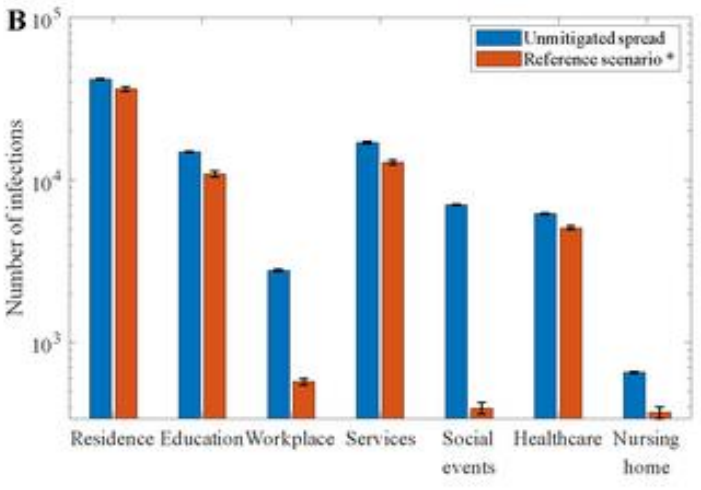
Agent based modelling: building a virtual city

- Virtual Szeged developed by a team at Pázmány University
  - 185 000 agents (citizens and commuters)
  - Realistic, high resolution spatial demography
  - Over 3000 locations (schools, workplaces, hospitals, etc.)
  - Daily routines
  - 10 minutes temporal resolution
  - Disease dynamics
  - Control measures
  - High flexibility to include any feature





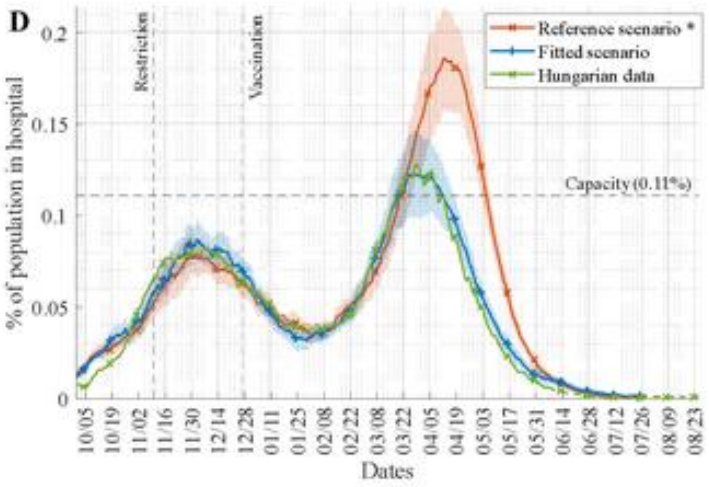




Parameter	Scenarios		
Closed from the 11th of November	C1: Large events, nursing homes	C1 + high schools, universities, most social events, curfew*	All non-essential locations, evening curfew
Quarantined people	Q1: diagnosed only	Q2: Q1+ household of diagnosed	Q3: Q2+ workmates or classmates of diagnosed*
Testing probability	Reference scenario*	10 times higher	20 times higher
Reopening timing	The 1st of April	1st May	1st June
Infectivity of novel variant	1.9 times higher	1.66 times higher*	1.5 times higher
Vaccinated daily	0.1%	0.2%*	0.3%
Vaccination order by	Occupational risk	Reference scenario*	Vulnerability

*Reference scenario

Worse scenario		Reference scenario				Better scenario



Microsimulation based quantitative analysis of COVID-19 management strategies

István Z. Reguly[1,2], Dávid Csercsik[1], János Juhász[1,3], Kálmán Tornai[1], Zsófia Bujtár[1], Gergely Horváth[1], Bence Keömley-Horváth[1,2], Tamás Kós[1], György Cserey[1], Kristóf Iván[1], Sándor Pongor[1], Gábor Szederkényi[1], Gergely Röst[4], Attila Csikász-Nagy[1,2,5]

[1] Faculty of Information Technology and Bionics, Pázmány Péter Catholic University, Budapest, Hungary
[2] Cytocast Kft., Vecsés, Hungary
[3] Institute of Medical Microbiology, Faculty of Medicine, Semmelweis University, Budapest, Hungary
[4] Bolyai Institute, University of Szeged, Szeged, Hungary
[5] Randall Centre for Cell and Molecular Biophysics, King's College London, London, United Kingdom

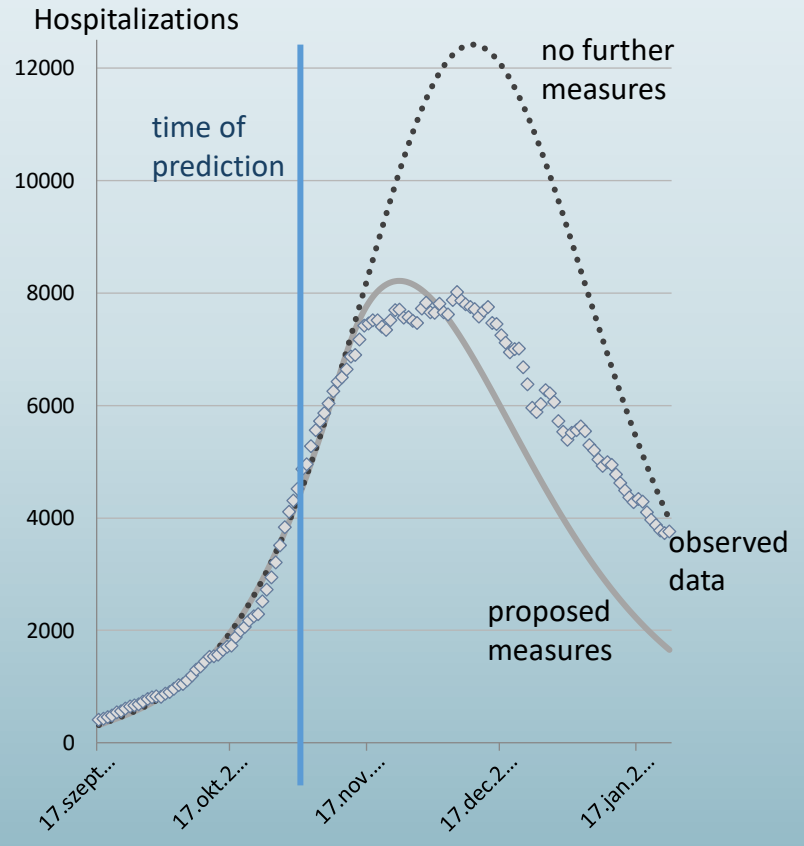
Short title

Pandemics management analysis by microsimulations

Role of mathematical modelling in informing decision making

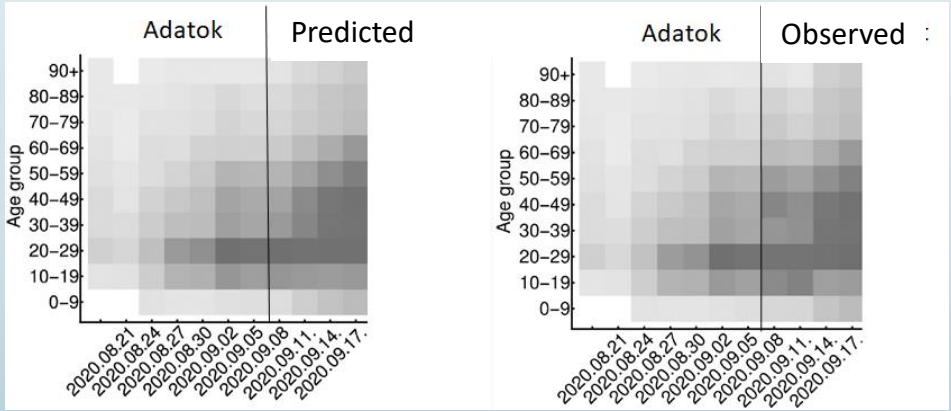
- We can not experiment with epidemics
- We must rely on mathematical models to analyse possible scenarios
- Models are useful:
  - to think and talk rigorously about the epidemics in quantitative terms
  - to explain what is going on
  - to make forecasts
  - to highlight complexity/simplicity
  - to understand trade-offs
  - to guide data collection
  - to evaluate past and future inverventions
  - to expand the evidence basis for informed decision making

- Models can be just as good as the data and information they rely on
- We need enhanced epidemiological surveillance: reliable, accurate, detailed, targeted data collection in real time
- We need some understanding of societal behaviour, triggers, reactions
- Without these, modelling is futile

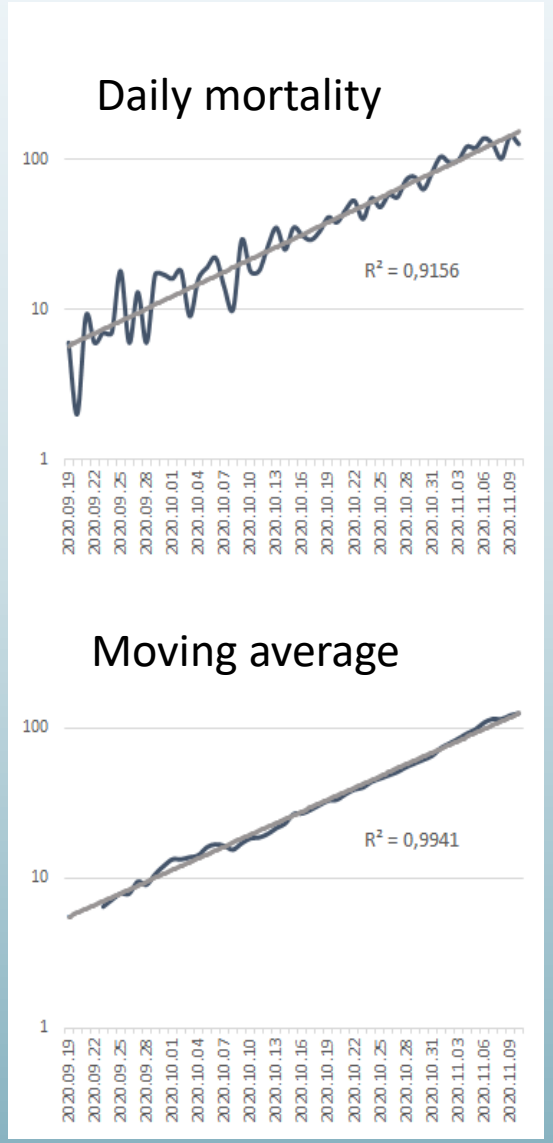


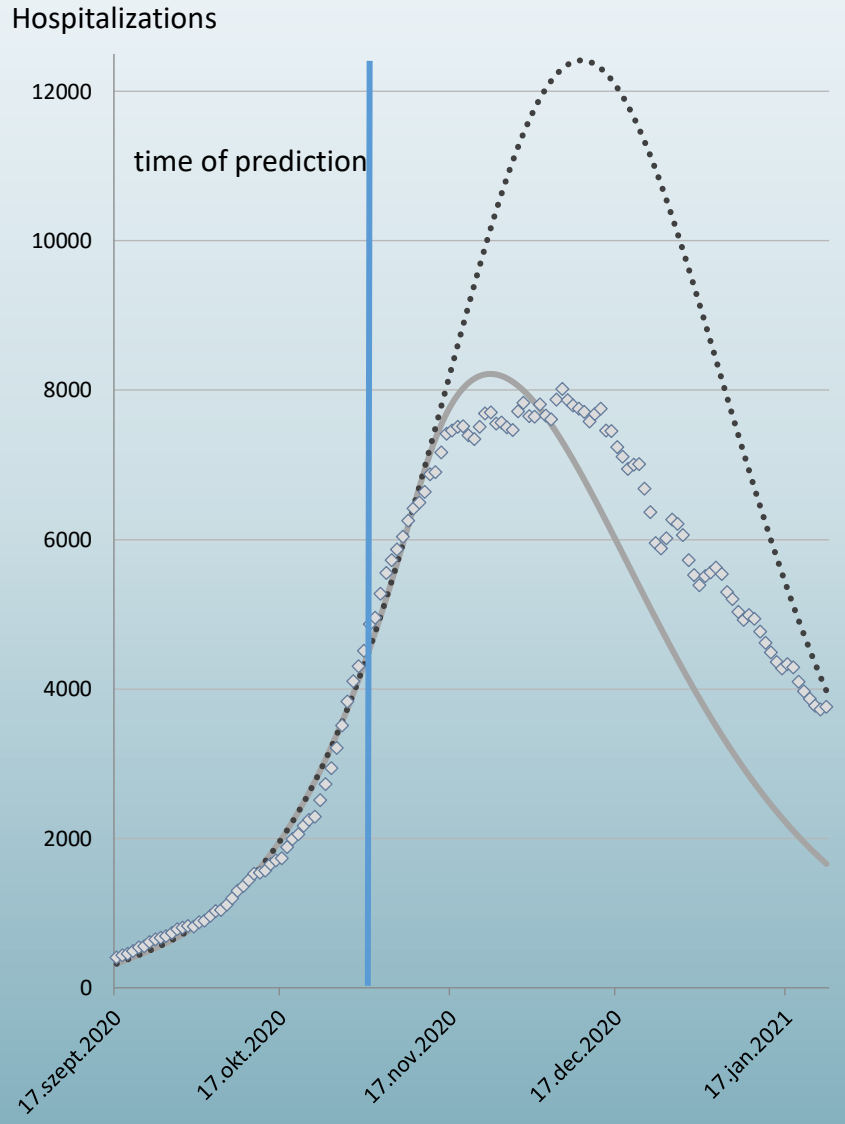
A key figure from a highest level meeting in early November 2020

Second wave (Fall 2020)



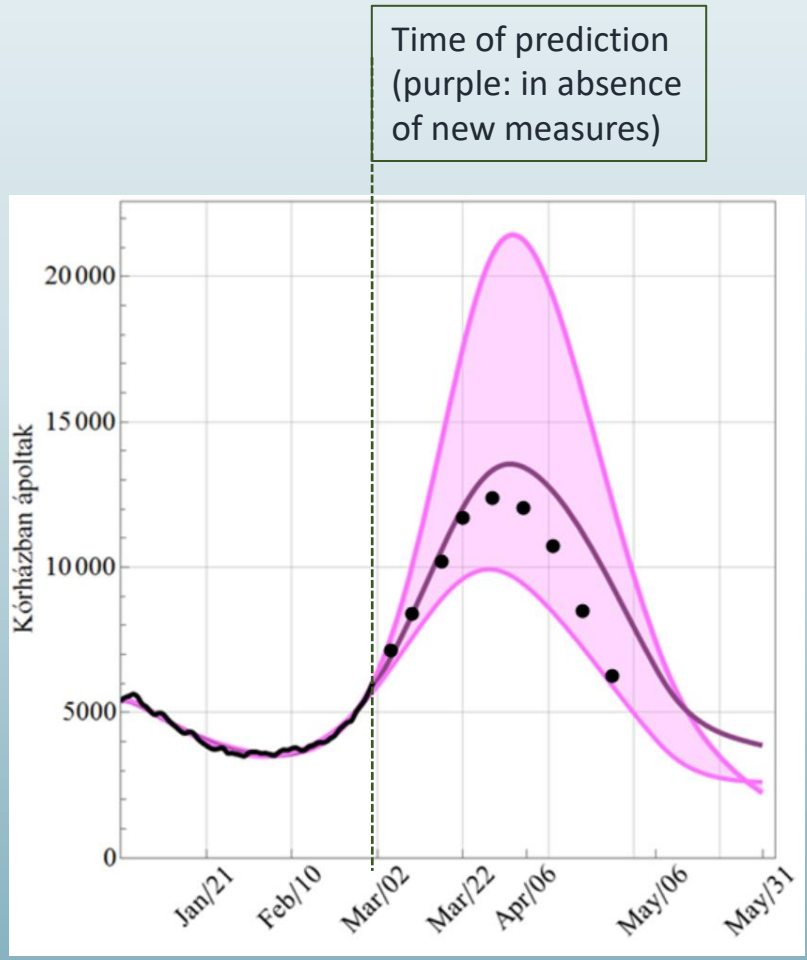
exponential growth
corresponds to R=1.31



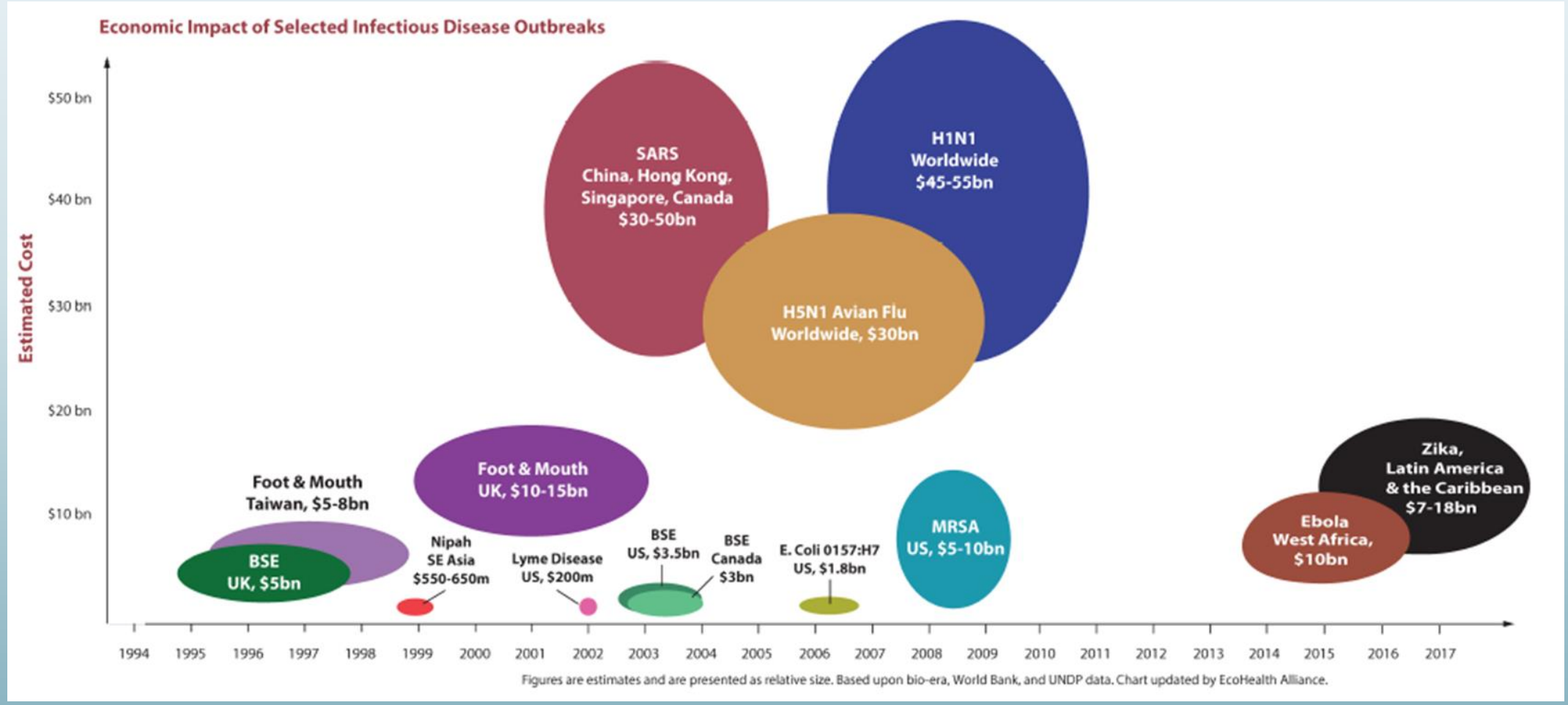


Major predictions resulting from mathematical epidemiology

- First wave: contact numbers should be reduced by at least 60% to suppress the outbreak (we verified that it happened)
- We reported first that suppression was successful
- We stated that upon relaxing the measures, we can expect a second wave
- We warned first of the coming large outbreak in August 2020
- We predicted that the number of deaths will increase in October
- November interventions used our modelling input and predictions
- We predicted the third wave in early January (by alpha variant)
- In the most critical phase, hospitals were informed about the peak burden by our calculations
- March interventions were informed by our calculations
- We reported first the peak of the third wave
- Relaxation of measures in the Spring (school openings) used our calculations
- In June we predicted that there will be a fourth wave



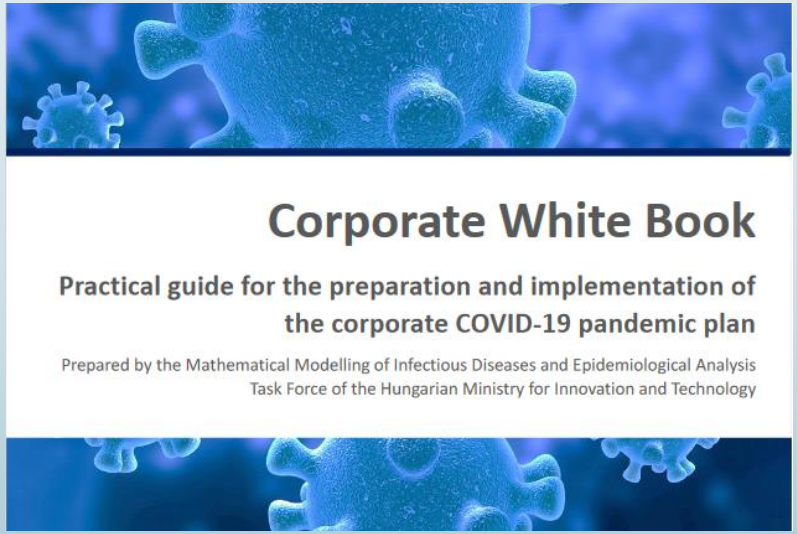
Huge economic impact of infectious disease outbreaks



https://www.preventionweb.net/blog/linking-health-environment-and-climate-reduce-disaster-risk

Costs of the pandemic

- High death toll
- Healthcare systems under extreme pressure
- Normal healthcare services disrupted
- Long COVID
- Societal costs: disruption of education, mental issues, conflicts in society, issues of trust
- Some positive side effect: reduction in other respiratory viruses (no influenza), fewer accidents, less pollution.
- Economy: sector dependent impacts
- US: $1.9 trillion COVID stimulus package
- EU: NextGenerationEU is a more than €800 billion temporary recovery instrument



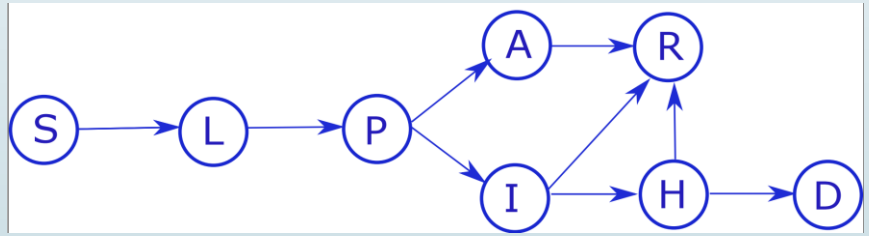
availaible in English:
https://vali.ifka.hu/medias/85/corporate_white_book.pdf

Nonlinear Dyn (2020) 102:1965–1986
https://doi.org/10.1007/s11071-020-05980-1

FEATURE ARTICLE

Nonlinear model predictive control with logic constraints for COVID-19 management

Tamás Péni · Balázs Csutak · Gábor Szederkényi · Gergely Röst



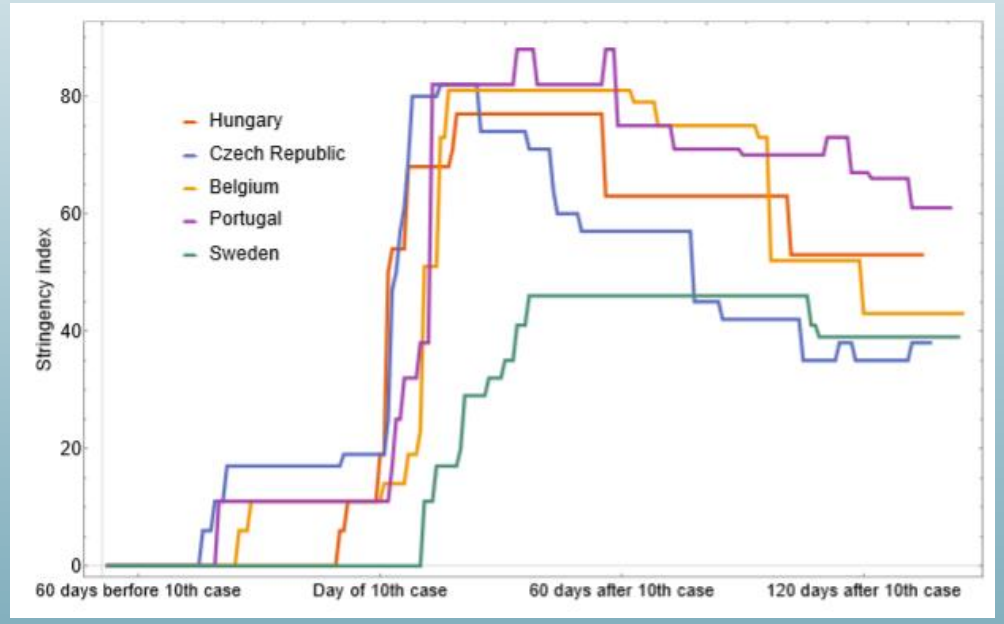
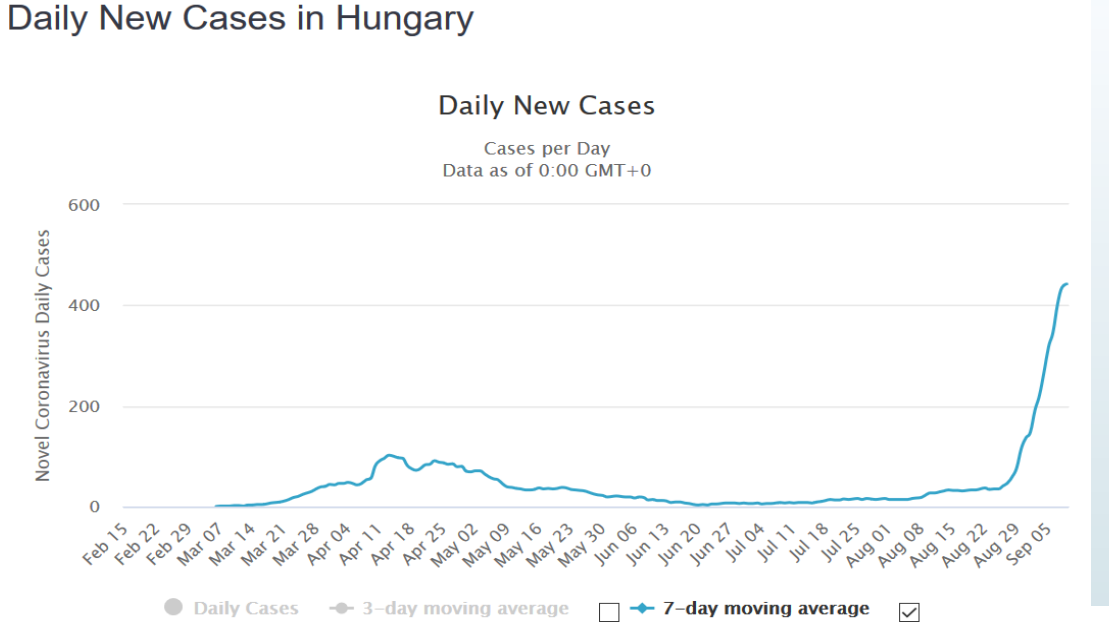
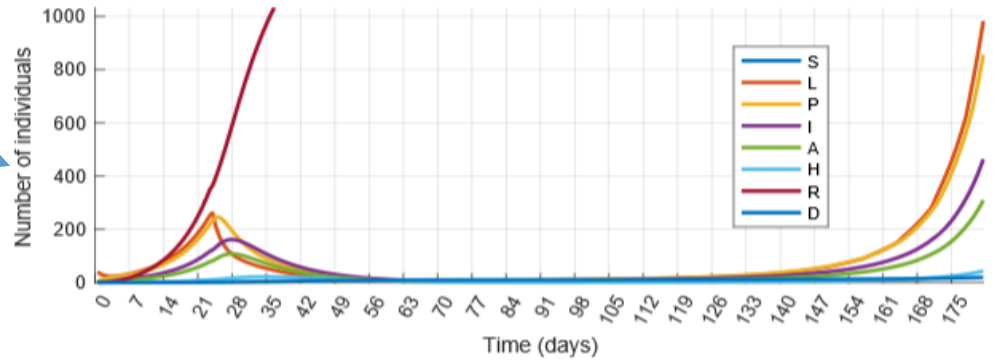
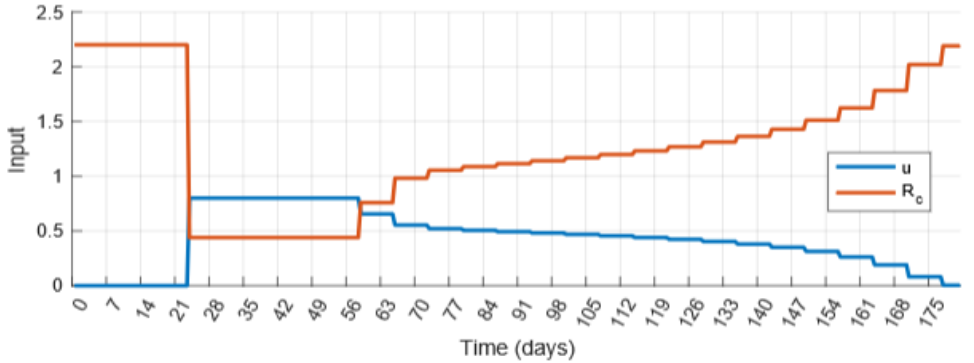


Figure was made in July!

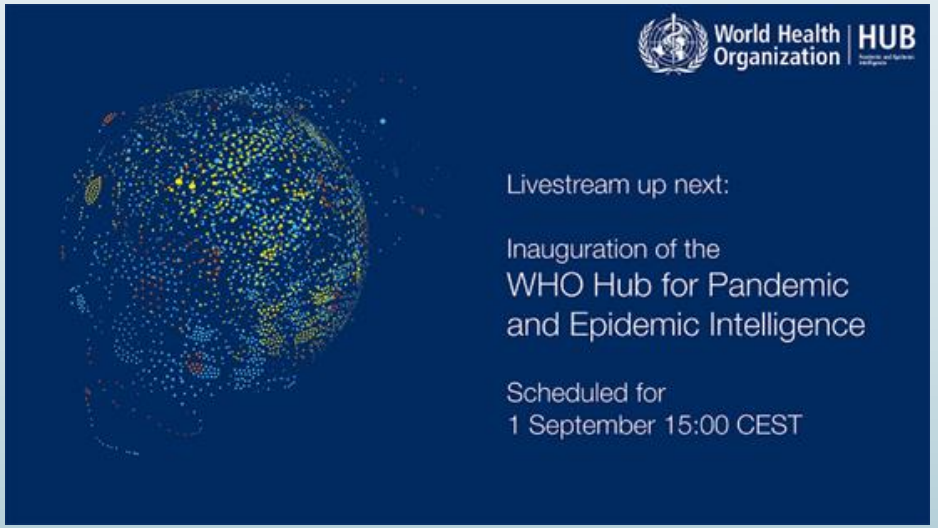


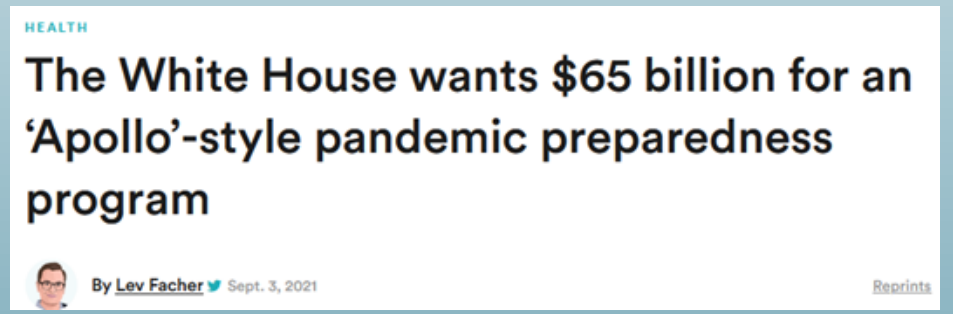




Innovative technologies needs to be integrated into public health systems

- World was unprepared (crucial institutions have been downsized in past decade)
- Societal behaviours and attitudes are paramount (fighting infodemics)
- Monitoring new virus variants is essential
- Comprehensive strategies are best
- Paradigm change is needed for 21st century pandemic preparedness, innovation and modern technologies surveillance and analysis (WHO, USA recognized this)





scientific reports

OPEN

Fleeing lockdown and its impact on the size of epidemic outbreaks in the source and target regions – a COVID-19 lesson

Maria Vittoria Barbarossa[1,3✉], Norbert Bogya[2], Attila Dénes[2], Gergely Röst[2], Hridya Vinod Varma[3] & Zsolt Vizi[2]

viruses

Article

Early Phase of the COVID-19 Outbreak in Hungary and Post-Lockdown Scenarios

Gergely Röst [1], Ferenc A. Bartha [1,*], Norbert Bogya [1], Péter Boldog [1], Attila Dénes [1], Tamás Ferenci [2], Krisztina J. Horváth [1], Attila Juhász [1,3], Csilla Nagy [1,3], Tamás Tekeli [1], Zsolt Vizi [1] and Beatrix Oroszi [1]

Fall 2021 Resurgence and COVID-19 Seroprevalence in Canada
Modelling waning and boosting COVID-19 immunity in Canada
A Canadian Immunization Research Network Study
August 17, 2021

David W. Dick[1], Lauren Childs[2], Zhilan Feng[3a,b], Jing Li[4], Gergely Röst[5], David L Buckeridge[6], Nick H Ogden[7], Jane M Heffernan[1]

Journal of Clinical Medicine

Article

Risk Assessment of Novel Coronavirus COVID-19 Outbreaks Outside China

Péter Boldog, Tamás Tekeli, Zsolt Vizi, Attila Dénes *, Ferenc A. Bartha and Gergely Röst

Can hesitancy be mitigated by free choice across COVID-19 vaccine types?

Kristóf Kutasi[1], Júlia Koltai[2,3,4], Ágnes Szabó-Morvai[5,11], Gergely Röst[6], Márton Karsai[4,7], Péter Biró[8,9,+,*], and Balázs Lengyel[10,11,+,**]

COVID-19 | Open Access | Published: 10 June 2021

Different approaches to quantify years of life lost from COVID-19

Tamás Ferenci

European Journal of Epidemiology (2021) | Cite this article

Adaptive group testing in a compartmental model of COVID-19

Attila Dénes, Tamás Tekeli, Gergely Röst

CORVINUS JOURNAL OF SOCIOLOGY AND SOCIAL POLICY VOL. 11 (2020)2, 139-146. DOI: 10.14267/CJSSP.2020.2.9

HUNGARY IN MASKS/"MASZK" IN HUNGARY

MÁRTON KARSAI,[1,2] JÚLIA KOLTAI,[3,4,1] ORSOLYA VÁSÁRHELYI,[3,1] GERGELY RÖST[6*]

Symptom-based testing in a compartmental model of COVID-19

Ferenc A. Bartha, János Karsai, Tamás Tekeli, and Gergely Röst

The shrinking families paradox and COVID-19

Péter Boldog, Gergely Röst

Monitoring behavioural responses during pandemic via reconstructed contact matrices from online and representative surveys

Júlia Koltai[1,2,3,+], Orsolya Vásárhelyi[3,4,+], Gergely Röst[5], and Márton Karsai[3,6,+,*]

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FEATURE ARTICLE

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EPIDEMIC MODEL FOR RISK-BASED TESTING AND QUARANTINE

A. DÉNES, G. RÖST AND T. TEKELI
Bolyai Institute, University of Szeged,

Microsimulation based evaluation of COVID-19 management strategies

István Z. Reguly[1,2], Dávid Csercsik[1], János Juhász[1,3], Kálmán Tornai[1], Zsófia Bujtár[1], Gergely Horváth[1], Bence Keömley-Horváth[1,2], Tamás Kós[1], György Cserey[1], Kristóf Iván[1], Sándor Pongor[1], Gábor Szederkényi[1], Gergely Röst[4], Attila Csikász-Nagy[1,5]

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Research

A hybrid PDE–ABM model for viral dynamics with application to SARS–CoV–2 and influenza

Sadegh Marzban, Renji Han, Nóra Juhász, and Gergely Röst

PROPENSITY MATRIX METHOD FOR AGE DEPENDENT STOCHASTIC INFECTIOUS DISEASE MODELS*

P. BOLDOG, N. BOGYA† AND ZS. VIZI‡

Modeling waning and boosting of COVID-19 in Canada with vaccination

Lauren Childs[1], David W Dick[2], Zhilan Feng[3a,b], Jane M Heffernan[2], Jing Li[4], Gergely Röst[5]

BMJ Global Health

Unequal burden of COVID-19 in Hungary: a geographical and socioeconomic analysis of the second wave of the pandemic

Beatrix Oroszi,[1] Attila Juhász,[2] Csilla Nagy,[2] Judit Krisztina Horváth,[1] Martin McKee [3], Róza Ádány[4,5]

Oroszi Beatrix, Horváth J. Krisztina, Túri Gergő, Krisztalovics Katalin, Röst Gergely

Az epidemiológiai surveillance és járványmatematikai előrejelzések szerepe a pandémiás hullámok megelőzésében, mérséklésében – hol tartunk most, és hová kellene eljutni

The role of epidemiological surveillance and mathematical forecasting in preventing and mitigating pandemic waves – what has been accomplished and what should be achieved