A System Dynamics-based Spatial Model to Explore Pandemic Preparedness and Response

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Presentation Overview

- Project Aims
- Requirements Gathering and Prioritisation Process
- Resource Modelling Tool
  - Data
  - Model
  - Interface
- Next Steps
PANDEM Project (H2020)

- Horizon 2020: Secure Societies Work Programme
- Phase I *demo project*
- Multi-disciplinary collaboration of seven institutions
- Project duration - Sept 2015-March 2017
- Project areas:
  - Surveillance
  - Communication
  - Governance
PANDEM Scope

- Review and assess **current best practice for** pandemic preparedness and response
- Identify **major gaps/improvement needs** and research priorities
- Identify **innovative solutions** for improved technologies, systems and capacity that would reduce health, security, environmental and economic impact of future pandemics

Methodology

- Review of tools, systems and practices at Member States, European Union and global level
- Review of previous EU research projects
- Key informant interviews with public health end-users
- Case studies: EU countries, USA and EU response to Ebola outbreak
- Expert workshops in Brussels: February and September 2016

<table>
<thead>
<tr>
<th>TOPIC</th>
<th>CURRENT GAPS</th>
<th>POSSIBLE SOLUTIONS</th>
<th>POTENTIAL IMPACT</th>
<th>IDEAL SITUATION WITHIN 5-10 YEARS</th>
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<tr>
<td>5.1 Population-based surveillance</td>
<td>Lack of baseline knowledge of community level data and information on impact of a pandemic. Little data available on people who do not seek health care. Poor capacity to estimate and monitor spread of infection and impact on essential services in society.</td>
<td>People-friendly platforms to promote the collection, analysis, and dissemination of pandemic data and information. Include Absenteeism work and schools.</td>
<td>Enables rapid risk assessments and estimate of impact of a new threat and thereby enables best possible use of counter measures.</td>
<td>Ability by all MS to quickly assess impact of a pandemic at community level, identify implications for essential services and plan response in real-time</td>
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</table>
Examples of Information Gathering Sources

- ECDC EWRS System
- GOARN Go Data
- National Systems: Ireland & Sweden
- Expert Workshops
Pandemic Planning: Summary of Gaps and Priorities

- **Investment case** for pandemic preparedness needs to be made at national level
- **Societal and economic impact** – cost of workplace absenteeism, maintenance of essential services
- Plans for **delivery systems** for countermeasures eg vaccines, anti-virals
- Lack of availability of tools for coordinated planning and response
- Need for **resource modelling tool and simulations** to guide resource allocation
Resource Modelling Challenge

• Epidemic curve generates health system pressures
• Resources Impact on Health outcomes
• Resource Examples:
  – Antivirals (for risk groups)
  – Vaccines
  – Hospital Beds
  – Ventilators
  – ICU Beds
• Outcomes
  – Absenteeism
  – Economic Impact
  – Serious illness
Resources Impact Flows...

http://www.cdc.gov/vaccines/vac-gen/images/vaccines-protect.jpg
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<th>Number of Health Workers</th>
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Development of a resource modelling tool to support decision makers in pandemic influenza preparedness: The AsiaFluCap Simulator

D5.1 Workshop to identify needs and innovations to strengthen pandemic

D6.1 Workshop on Integrated Solutions for Pandemic Management

PANDEM-CAP – Requirements Gathering

PANDEM-CAP Simulator

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*Transmission Model, User Interface, Resource Model, NUTS2 Data*
Asia Flucap Model

\[ R_0 = \frac{qK}{\delta} + \frac{qK}{\tau} + P_x \frac{qK}{\gamma_x} + P_m \frac{qK}{\gamma_m} + P_c \frac{qK_h}{\gamma_c} \]

\[ \frac{dS}{dt} = -SP_x - qK(1 - p_x) \frac{S}{N - D}(A + I_a + I_{a2}) \]

\[ q(1 - p_{gh})K_h \frac{S}{N - D}(I_h + V) \]

\[ \frac{dE}{dt} = qK(1 - p_x) \frac{S}{N - D} (A + I_a + I_{a2} + I_{m1} + I_{m2} + I_{m3} + I_{m4}) \]

\[ q(1 - p_{gh})K_h \frac{S}{N - D}(I_h + V) - E\sigma \]

\[ \frac{dA}{dt} = E\sigma - A\delta \]

\[ \frac{dI_a}{dt} = A\delta\rho_a - I_a\tau \]

\[ \frac{dI_{a2}}{dt} = I_a\tau - I_{a2}\gamma_a \]
## SEIR Resource Model Parameters

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</tbody>
</table>
Implementation in R

• It is a dialect of the S language, developed at Bell Laboratories
• Open source, functional & object-oriented language
• R’s mission is to enable the best and most thorough exploration of data possible (Chambers 2008).
R Supports Data Exploration

“Data exploration is the art of looking at your data, rapidly generating hypotheses, quickly testing them, then repeating again and again and again.” (Wickham and Grolemund 2017).
Energy & Health Examples
deSolve in R

R Source code

function

Net flow equations go here

Call to ode function (initState, times, func, params, method)

ode

Data frame

Return results

Call for each time step

(time, state, params)
Translator for Vensim files into deSolve files

This folder contains a utility that can be used to generate deSolve files in R based on the equations outputted from Vensim. Equations should be outputted in computational order.

Maths functions that are available in R can be translated (once they have the same name and parameter list), but specialised Vensim functions are not implemented.

The instructions are as follows:

- Save the Vensim equations to .txt
- Create a conversion script .R
- Run the conversion script

Here is a sample conversion script (TestScript.R) that converts Vensim equations from SIR.txt into a deSolve file SIR.R

```r
source("reader/conv_to_deSolve.R")
output<-sim$translate_vensim("./reader/SIR.txt")
sim$save_model(output,"./reader/SIR.R")
```

[https://github.com/JimDuggan/SDMR](https://github.com/JimDuggan/SDMR)
Implementing models in deSolve
User Interface

- Plot
- Epicurve
- Density map

**Scenario**
- BaseRun
- Extra Resources
- Severe

**Number of Cases**
- Time in Days

---

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Costs & Pressure

Economic

- BaseRun
- Extra Resources
- Severe

Net Resources

- BaseRun
- Extra Resources
- Severe

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Absenteism

Absenteism from School

Absenteism from Work

Scenario

- BaseRun
- Extra Resources
- Severe

Number of Days Lost

Time in days

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Demonstration
Summary & Future Work

- **At MS level:**
  - Estimate resource gaps based on quantities of resources needed (from simulation) and availability (input from MS)
  - Show the effect of resource gaps on key indicators, such as costs

- **At EU level:**
  - Allow for better communication and cooperation
  - Shared situational awareness
  - Common terminology and model
  - Standardized data
Acknowledgements

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National University of Ireland Galway (NUIG, co-ordinator)
Health security and pandemic preparedness, management, coordination, dissemination, information and communications technology

WHO Regional Office for Europe – surveillance, governance

Public Health Agency of Sweden (Folkhalsomyndigheten, FoHM) – risk assessment, surveillance

Swedish Defence Research Agency (Totalforsvarets Forskningsinstitut, FOI) – threat analysis, crisis management, civil protection, defence, security

London School of Hygiene and Tropical Medicine (LSHTM) – governance, legal frameworks, ethics, human rights

Université catholique de Louvain (UCL) – microbiology, biosecurity, defence

IGS Strategic Communications – communications, social media