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Simple models of epidemiology

THE UNESCO CHAIR OF INTERDISCIPLINARY STUDIES / SMOLUCHOWSKI INSTITUTE OF PHYSICS

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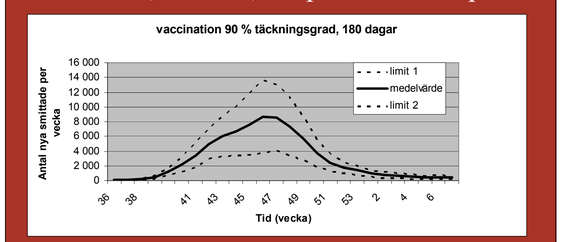
Social network of contacts:

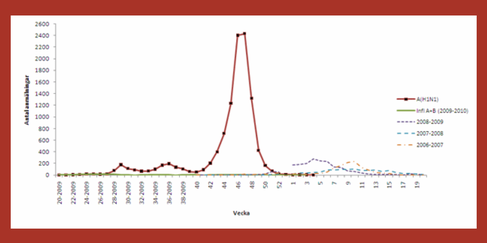
In an SIR-type model, the population is split into three different groups and the majority of the population is placed in the susceptible compartment. All information about society is used in microsimulation, so it can give better prediction, then differential equations

All information about society is used in microsimulation, so it can give better prediction, then differential equations. Simplified compartmental models provide inadequate representations because contacts between susceptible and infectious persons are not random. We can use a lot of information in this consideration, which are provided by government. Another reason is that, there is possible to run algorithms for society of whole country-Sweden and there are not too time consuming, e.g. one 180 day simulation take about less than 1h on personal computer.

Database of programme takes account data from:

1. National population register- all information about sex, age etc
2. Employment register- it provides list of employee or students
3. Geography database -100x100 coordinates of houses, schools, hospitals or workplaces





Picture 4) No. of infections per week in simulation (upper graph by L. Brouwers) and cases collected by The Swedish Institute for Infectious Disease Control (lower graph by SMI).

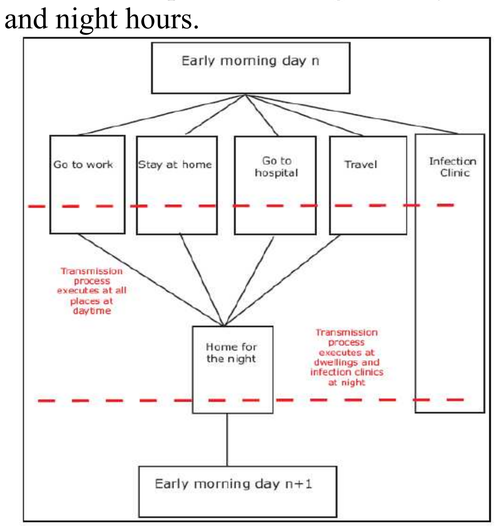
Bernuolli and Smallpox

This Swiss mathematician was the first to express the proportion of susceptible individuals of an endemic infection in terms of the force of infection and life expectancy. His work describe smallpox, which cause a lot of epidemics in big European cities at his time. Smallpox devastated earlier the native Amerindian population and was an important factor in the conquest of the Aztecs and the Incas by the Spaniards.

In Poland smallpox last time appear in Wroclaw in 1963, but it was stopped by the actions of the government and epidemiologists. Moreover smallpox was eradicated by WHO in 1979. Bernoulli actually used date provided from Wroclaw to estimate his model.

Economic Consequences to Society of Pandemic H1N1 Influenza

Disease transmission is performed twice daily at 9 am and 5 pm. Programme checks where are all persons during that day hours and night hours.

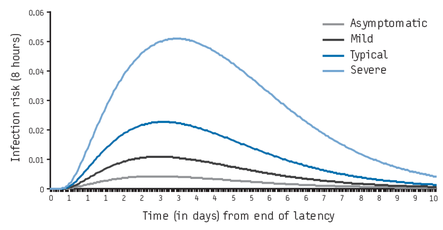


Picture 1) The daily routines for the simulated persons. [L. Brouwers]

Additional contacts (and transmission) are included in model in two ways (Sweden is divided into 81 regions with their own characteristics of density or intensivity of traveling):

1. Neighbourhood
2. Travel

We have for exmaple profiles of probability of sending infections



Picture 2) Profile of probability (sending H1N1) [adopted F. Carrat].

The outbreak of pandemic influenza in Sweden starts depend of method in June or in September. R_0 -value corresponding approximately to 1.4 in main model, because that was observed in New Zealand during their outbreak. The viral infectivity is markedly initially R_0 value of approximately 2.1 in preliminary method.

$$R_0 = \frac{-\ln\left(\frac{A}{S_0}\right)}{1-\frac{A}{S_0}} \qquad (1)$$

Immunity was calibrated in model to obtain R_0- 1.4

S_0: Total number of susceptible individuals before the outbreak

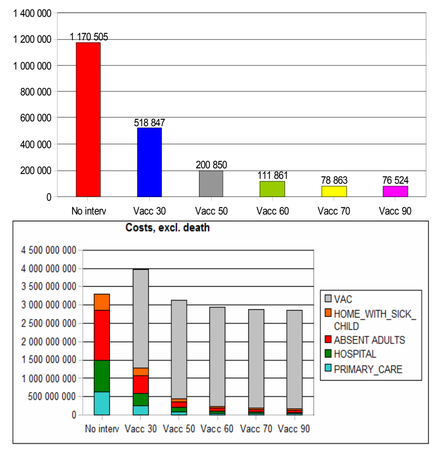
A: Total number of susceptible individuals after the outbreak

This formula is defined as is the average number of individuals a typical person infects under his/her full infectious period, in a fully susceptible population.

To compare the societal costs of the scenarios, the following costs—obtained from health economists at the Swedish Institute for Infectious Disease Control—were used.

- Cost of one day's absence from work, for a worker: SEK 900.
- Cost of treatment by a doctor in primary care: SEK 2000.
- Cost of one day's inpatient care: SEK 8000.
- Cost of vaccine and administration of vaccination for one person: SEK 300.

The following scenarios were compared: no response, the vaccination coverage of 30%, 50%, 60%, 70% or 90% in simulation.



Picture 3) No. of infections (upper graph) and cost of pandemia (lower graph) for different scenarios [by L. Brouwers].

Wrocław - from the beginig of smallpox epidemiology modeling up to erudation of disease

I simply wish that, in a matter which so closely concerns the well-being of mankind, no decision shall be made without all the knowledge which a little analysis and calculation can provide.

Daniel Bernoulli, presenting his estimates of smallpox

Royal Academy of Sciences-Paris, 30 April 1760

Bernoulii based at work of famous British astronomer – Edmund Halley „An Estimate of the Degrees of the Mortality of Mankind, drawn from curious Tables of the Births and Funerals at the City of Breslaw" published in Philosophical Transactions 196 (1692/1693). In 17th century English Breslaw means Breslau-German name of Wroclaw. In beginning of his publication Halley wrote his purpose: „This *Defect* seems in a great measure to be satisfied by the late curious Tables of the Bills of *Mortality* at the City of *Breslaw,* lately communicated to this Honorable Society by Mr. *Just ell*, wherein both the *Ages* and *Sexes* of all that die are monthly delivered, and compared with the number of the *Births*, for Five Years last past 1687, 88, 89, 90, 91, seeming to be done with all the Exactness and Sincerity possible." Later he described Wroclaw:

„This City of *Breslaw* is the Capital City of the Province of *Silesia*; or, as the *Germans* call it, *Schlesia*, and is situated on the Western Bank of the River *Oder*, anciently called *Viadrus*; near the Confines of *Germany* and *Poland"*

Age in years	Survivors according to Halley	Not having had smallpox	Having had smallpox	Catching smallpox each year	smallpox each year	Totall smallox deaths	Death of other diseases each year
0	1300	1300	0				
1	1000	896	104	137	17,1	17,1	283
2	855	685	170	99	12,4	29,5	133
3	798	571	227	78	9,7	39,2	47
4	760	485	275	66	8,3	47,5	30
5	732	416	316	56	7	54,5	21
6	710	359	351	48	6	60,5	16
7	692	311	381	42	5,2	65,7	12,8
8	680	272	408	36	4,5	70,2	7,5
9	670	237	433	32	4	74,2	6
10	661	208	453	28	3,5	77,7	5,5
11	653	182	471	24,4	3	80,7	5
12	646	160	486	21,4	2,7	83,4	4,3
13	640	140	500	18,7	2,3	85,7	3,7
14	634	123	511	16,6	2,1	87,8	3,9
15	628	108	520	14,4	1,8	89,6	4,2
16	622	94	528	12,6	1,6	91,2	4,4
17	616	83	533	11	1,4	92,6	4,6
18	610	72	538	9,7	1,2	93,8	4,8
19	604	63	541	8,4	1	94,8	5
20	598	56	542	7,4	0,9	95,7	5,1
21	592	48,5	543	6,5	0,8	96,5	5,2
22	586	42,5	543	5,6	0,7	97,2	5,3
23	579	37	542	5	0,6	97,8	6,4
24	572	32,4	540	4,4	0,5	98,3	6,5

Table 1) Smallpox in Wroclaw [D. Bernoulli]

Bernoulli has constructed the second (Table 2) at the end of this Memoir, in which the first two columns are the same as in the first (Table 1), though he has given the second column another name, 'natural state with smallpox', in contradistinction to the third column, which shows the 'state without smallpox' and which gives the number of survivors each year assuming that nobody must die of smallpox. Difference between second and third column gave him a gain in people's lives. He introduced 'total quantity of life' of the whole generation, for each of the two states, for the sum of all the numbers of the second column and of the third column respectively (table 2).

Making this deduction, we obtain the total quantity of life for the state free from smallpox, with the whole tribute paid, which must be compared with tribute for the natural state. If take expected values of variables in second in third column (sum all multiplication of age and values in column and we divide these numbers by 1300) we will have the average life for the natural state as 26 years 7 months, for the state without smallpox and without tribute as 29 years 9 months and for the state free from smallpox. Under these assumptions an individual's expectation of life at birth would increase from 26 years 7 months to 29 years 9 months.

Age in years	Natural state with smallpox	State without smallpox
0	1300	1300
1	1200	1171
2	855	881,8
3	798	833,3
4	760	802
5	732	779,8
6	710	762,8
7	692	749,1
8	680	740,9
9	670	734,4
10	661	728,4
11	653	722,9
12	646	718,2
13	640	741,1
14	634	709,7
15	628	705
16	622	700,1
17	616	695
18	610	689,6
19	604	684
20	598	678,2
21	592	672,3
22	586	666,3
23	579	659
24	572	651,7
25	565	644,3

Table 2) Gain in life [D. Bernoulli]

Related articles: „Belastning på samhället vid ett utbrott av den nya pandemiska influensan A(H1N1) 2009" 2009

Brouwers L, Camitz M, Cakici B, Mäkilä K, Saretok P. MicroSim: modeling the Swedish population.

Bernoulli D, "An attempt at a new analysis of the mortality caused by smallpox and of the advantages of inoculation to prevent it", a translation by Sally Blower Mem Math Phy Acad Roy Sci Paris 1766

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