
# Modeling of Diseases

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# What is a dynamic model?

**System Dynamics is a computer-based mathematical modeling approach for strategy development and better decision making in complex systems.**

# From Model to Action: Using a System Dynamics Model of Chronic Disease Risks to Align Community Action

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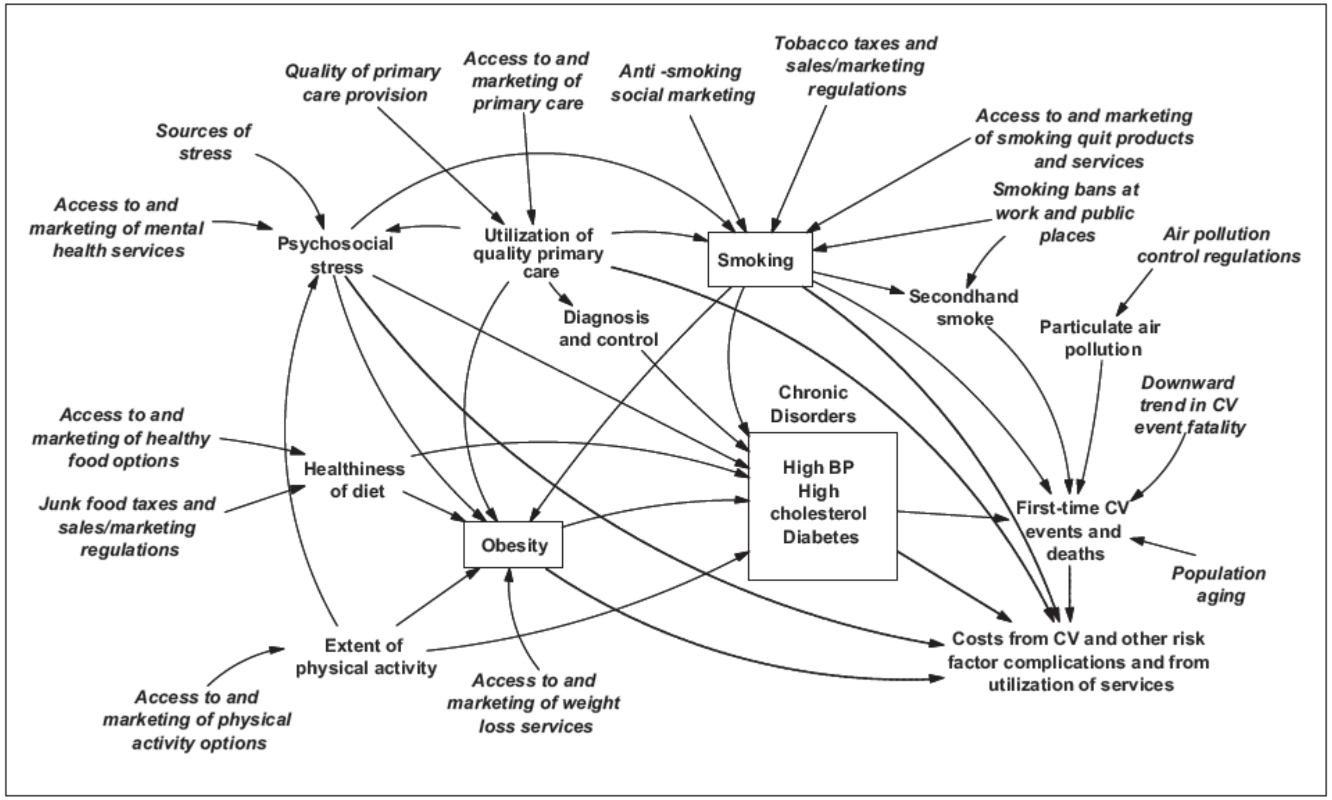
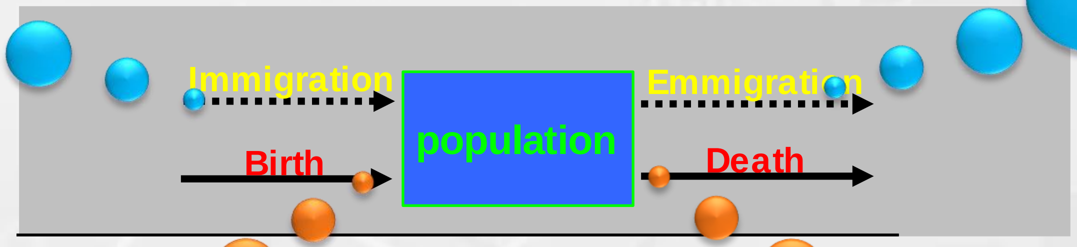



**FIGURE 1** Causal Framework of the System Dynamics Model of Cardiovascular (CV) Disease Risks

# A simple population dynamic model

Annual immigration rate=0.02
Means every year 2 move in occur in 100 population

Annual emigration rate=0.01
Means every year 1 walking out occur in 100 population



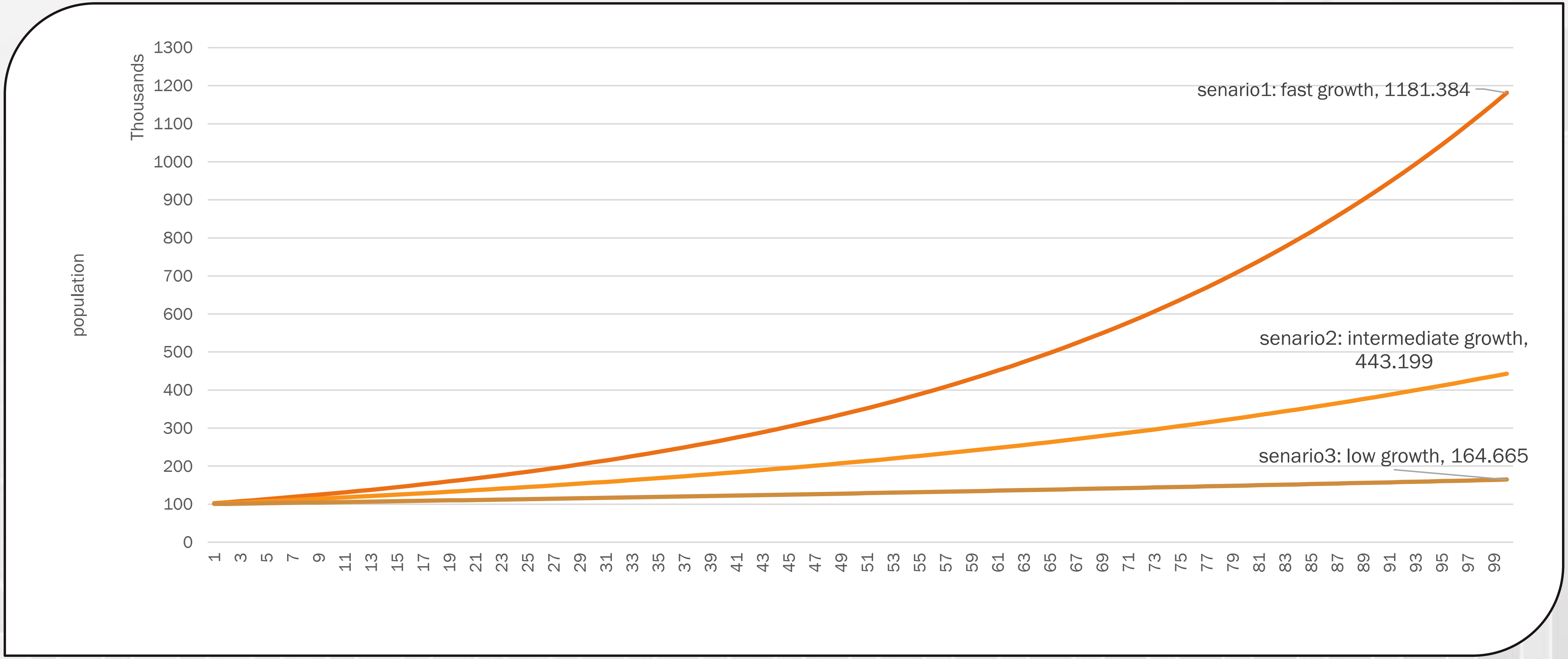

Annual birth rate=0.04
Means every year 4 births occur in 100 population

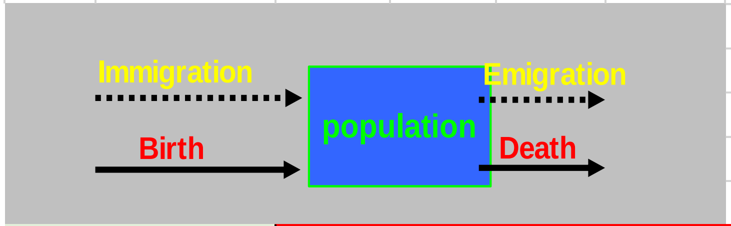
Annual death rate=0.025
Means every year 2.5 deaths occur in 100 population

# Coefficients in three scenarios

| | Fast growth senario1 | Intermediate senario2 | Low growth senario3 |
|---|---|---|---|
| imm. rate | 0.02 | 0.015 | 0.01 |
| emmi. rate | 0.01 | 0.01 | 0.01 |
| birth rate | 0.04 | 0.035 | 0.03 |
| death rate | 0.025 | 0.025 | 0.025 |

# The trend of population in 100 years in three different scenarios






| | senario1 | senario2 | senario3 |
|---|---|---|---|
| imm. rate | 0.02 | 0.015 | 0.01 |
| emmi. rate | 0.01 | 0.01 | 0.01 |
| birth rate | 0.04 | 0.035 | 0.03 |
| death rate | 0.025 | 0.025 | 0.025 |

| | | senario1: fast growth | | | | | senario2: intermediated growth | | | | | | senario3: low growth | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| year | population at the beginning of year | number death | number birth | number immig. | number emmi. | population at the end of year | population at the beginning of year | number death | number birth | number immig. | number emmi. | population at the end of | population at the beginning | number death | number birth | number immig. | number emmi. | population at the end of year |
| 1 | 100000 | 2500 | 4000 | 2000 | 1000 | 102500 | 100000 | 2500 | 3500 | 1500 | 1000 | 101500 | 100000 | 2500 | 3000 | 1000 | 1000 | 100500 |
| 2 | 102500 | 2562.5 | 4100 | 2050 | 1025 | 105063 | 101500 | 2537.5 | 3552.5 | 1522.5 | 1015 | 103023 | 100500 | 2512.5 | 3015 | 1005 | 1005 | 101003 |
| 3 | 105063 | 2626.6 | 4202.5 | 2101.3 | 1050.63 | 107690 | 103023 | 2575.6 | 3605.81 | 1545.35 | 1030.23 | 104568 | 101003 | 2525.1 | 3030.09 | 1010.03 | 1010.03 | 101508 |
| 4 | 107690 | 2692.3 | 4307.6 | 2153.8 | 1076.9 | 110382 | 104568 | 2614.2 | 3659.88 | 1568.52 | 1045.68 | 106137 | 101508 | 2537.7 | 3045.24 | 1015.08 | 1015.08 | 102016 |
| 5 | 110382 | 2759.6 | 4415.3 | 2207.6 | 1103.82 | 113142 | 106137 | 2653.4 | 3714.8 | 1592.06 | 1061.37 | 107729 | 102016 | 2550.4 | 3060.48 | 1020.16 | 1020.16 | 102526 |
| 6 | 113142 | 2828.6 | 4525.7 | 2262.8 | 1131.42 | 115971 | 107729 | 2693.2 | 3770.52 | 1615.94 | 1077.29 | 109345 | 102526 | 2563.2 | 3075.78 | 1025.26 | 1025.26 | 103039 |
| 7 | 115971 | 2899.3 | 4638.8 | 2319.4 | 1159.71 | 118870 | 109345 | 2733.6 | 3827.08 | 1640.18 | 1093.45 | 110985 | 103039 | 2576 | 3091.17 | 1030.39 | 1030.39 | 103554 |
| 8 | 118870 | 2971.8 | 4754.8 | 2377.4 | 1188.7 | 121842 | 110985 | 2774.6 | 3884.48 | 1664.78 | 1109.85 | 112650 | 103554 | 2588.9 | 3106.62 | 1035.54 | 1035.54 | 104072 |
| 9 | 121842 | 3046.1 | 4873.7 | 2436.8 | 1218.42 | 124888 | 112650 | 2816.3 | 3942.75 | 1689.75 | 1126.5 | 114340 | 104072 | 2601.8 | 3122.16 | 1040.72 | 1040.72 | 104592 |
| 10 | 124888 | 3122.2 | 4995.5 | 2497.8 | 1248.88 | 128010 | 114340 | 2858.5 | 4001.9 | 1715.1 | 1143.4 | 116055 | 104592 | 2614.8 | 3137.76 | 1045.92 | 1045.92 | 105115 |
| 11 | 128010 | 3200.3 | 5120.4 | 2560.2 | 1280.1 | 131210 | 116055 | 2901.4 | 4061.93 | 1740.83 | 1160.55 | 117796 | 105115 | 2627.9 | 3153.45 | 1051.15 | 1051.15 | 105641 |
| 12 | 131210 | 3280.3 | 5248.4 | 2624.2 | 1312.1 | 134490 | 117796 | 2944.9 | 4122.86 | 1766.94 | 1177.96 | 119563 | 105641 | 2641 | 3169.23 | 1056.41 | 1056.41 | 106169 |
| 13 | 134490 | 3362.3 | 5379.6 | 2689.8 | 1344.9 | 137852 | 119563 | 2989.1 | 4184.71 | 1793.45 | 1195.63 | 121356 | 106169 | 2654.2 | 3185.07 | 1061.69 | 1061.69 | 106700 |
| 14 | 137852 | 3446.3 | 5514.1 | 2757 | 1378.52 | 141298 | 121356 | 3033.9 | 4247.46 | 1820.34 | 1213.56 | 123176 | 106700 | 2667.5 | 3201 | 1067 | 1067 | 107234 |
| 15 | 141298 | 3532.5 | 5651.9 | 2826 | 1412.98 | 144830 | 123176 | 3079.4 | 4311.16 | 1847.64 | 1231.76 | 125024 | 107234 | 2680.9 | 3217.02 | 1072.34 | 1072.34 | 107770 |
| 16 | 144830 | 3620.8 | 5793.2 | 2896.6 | 1448.3 | 148451 | 125024 | 3125.6 | 4375.84 | 1875.36 | 1250.24 | 126899 | 107770 | 2694.3 | 3233.1 | 1077.7 | 1077.7 | 108309 |
| 17 | 148451 | 3711.3 | 5938 | 2969 | 1484.51 | 152162 | 126899 | 3172.5 | 4441.47 | 1903.49 | 1268.99 | 128802 | 108309 | 2707.7 | 3249.27 | 1083.09 | 1083.09 | 108851 |
| 18 | 152162 | 3804.1 | 6086.5 | 3043.2 | 1521.62 | 155966 | 128802 | 3220.1 | 4508.07 | 1932.03 | 1288.02 | 130734 | 108851 | 2721.3 | 3265.53 | 1088.51 | 1088.51 | 109395 |
| 19 | 155966 | 3899.2 | 6238.6 | 3119.3 | 1559.66 | 159865 | 130734 | 3268.4 | 4575.69 | 1961.01 | 1307.34 | 132695 | 109395 | 2734.9 | 3281.85 | 1093.95 | 1093.95 | 109942 |

# Formula of the model

| | A | B | C | D | E | F | G | H | I | J | K | L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | senario1 | senario2 | senario3 | |
| 2 | | | | | | | imm. rate | | 0.02 | 0.015 | 0.01 | |
| 3 | | | | | | | emmi. rate | | 0.01 | 0.01 | 0.01 | |
| 4 | | | | | | | birth rate | | 0.04 | 0.035 | 0.03 | |
| 5 | | | | | | | death rate | | 0.025 | 0.025 | 0.025 | |
| 6 | | | | | | | | | | | | |
| 7 | | | senario1: fast growth | | | | | senario2: intermediated growth | | | | |
| 8 | year | population at the beginning of year | number death | number birth | number immig. | number emmi. | population at the end of year | population at the beginning of year | number death | number birth | number immig. | number emmi. |
| 9 | 1 | 100000 | =B9*$I$5 | =B9*$I$4 | =B9*$I$2 | =$B9*$I$3 | =ROUND(B9+(D9+E9)-(C | 100000 | =H9*$J$5 | =H9*$J$4 | =H9*$J$2 | =H9*$J$3 |
| 10 | 2 | =G9 | =B10*$I$5 | =B10*$I$4 | =B10*$I$2 | =$B10*$I$3 | =ROUND(B10+(D10+E10 | =M9 | =H10*$J$5 | =H10*$J$4 | =H10*$J$2 | =H10*$J$3 |
| 11 | 3 | =G10 | =B11*$I$5 | =B11*$I$4 | =B11*$I$2 | =$B11*$I$3 | =ROUND(B11+(D11+E11 | =M10 | =H11*$J$5 | =H11*$J$4 | =H11*$J$2 | =H11*$J$3 |
| 12 | 4 | =G11 | =B12*$I$5 | =B12*$I$4 | =B12*$I$2 | =$B12*$I$3 | =ROUND(B12+(D12+E12 | =M11 | =H12*$J$5 | =H12*$J$4 | =H12*$J$2 | =H12*$J$3 |
| 13 | 5 | =G12 | =B13*$I$5 | =B13*$I$4 | =B13*$I$2 | =$B13*$I$3 | =ROUND(B13+(D13+E13 | =M12 | =H13*$J$5 | =H13*$J$4 | =H13*$J$2 | =H13*$J$3 |
| 14 | 6 | =G13 | =B14*$I$5 | =B14*$I$4 | =B14*$I$2 | =$B14*$I$3 | =ROUND(B14+(D14+E14 | =M13 | =H14*$J$5 | =H14*$J$4 | =H14*$J$2 | =H14*$J$3 |
| 15 | 7 | =G14 | =B15*$I$5 | =B15*$I$4 | =B15*$I$2 | =$B15*$I$3 | =ROUND(B15+(D15+E15 | =M14 | =H15*$J$5 | =H15*$J$4 | =H15*$J$2 | =H15*$J$3 |

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# Dynamic modeling of female neutering interventions for free-roaming dog population management in an urban setting of southeastern Iran

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Understanding dynamics of free-roaming dog (FRD) population is critical for planning and implementation of dog population management programs. FRD population size estimation as well as dynamic modeling of dog population under different female dog neutering interventions were investigated in order to determine the most appropriate animal birth control approach. We performed population size estimate of dogs using sight-resight surveys by photography in a randomly selected 25 blocks of the city and all the suburbs of greater Kerman area. Main demographic features were characterized and the dog density distribution was mapped. A dynamic model was developed to predict free-roaming dog population variations after 5 and 10 years. Different scenarios based on 10, 30, 50, 60 and 70% female dog sterilization were considered to predict the effects of animal birth control measures. Free roaming dog population was estimated at 6781 dogs (65.3% males) in Kerman and suburbs with several major population hotspots. Analysis of the dog locations within the city showed that the largest proportion of the dogs were observed in the vacant lots (46.2%). Modeling predictions indicated that, in the absence of management, the free-roaming dog population could increase from a baseline of 6781 to 13,665 dogs (2.02 fold increase) in 5 years and to 19,376 dogs in 10 years (2.86 fold increase). Using a population dynamics model, we simulated five neutering coverages to explore the impact of female neutering on free-roaming dog population size. The 5-year projections of the model have shown that 50% annual female dog sterilization significantly reduced free-roaming dog population by 0.44 comparing to the baseline population. Findings of the present study improve our knowledge on the nature and extent of dog population dynamics in Iran. Effective population control and selection of the most appropriate neutering interventions require a comprehensive knowledge of the characteristics and dynamics of FRD population.

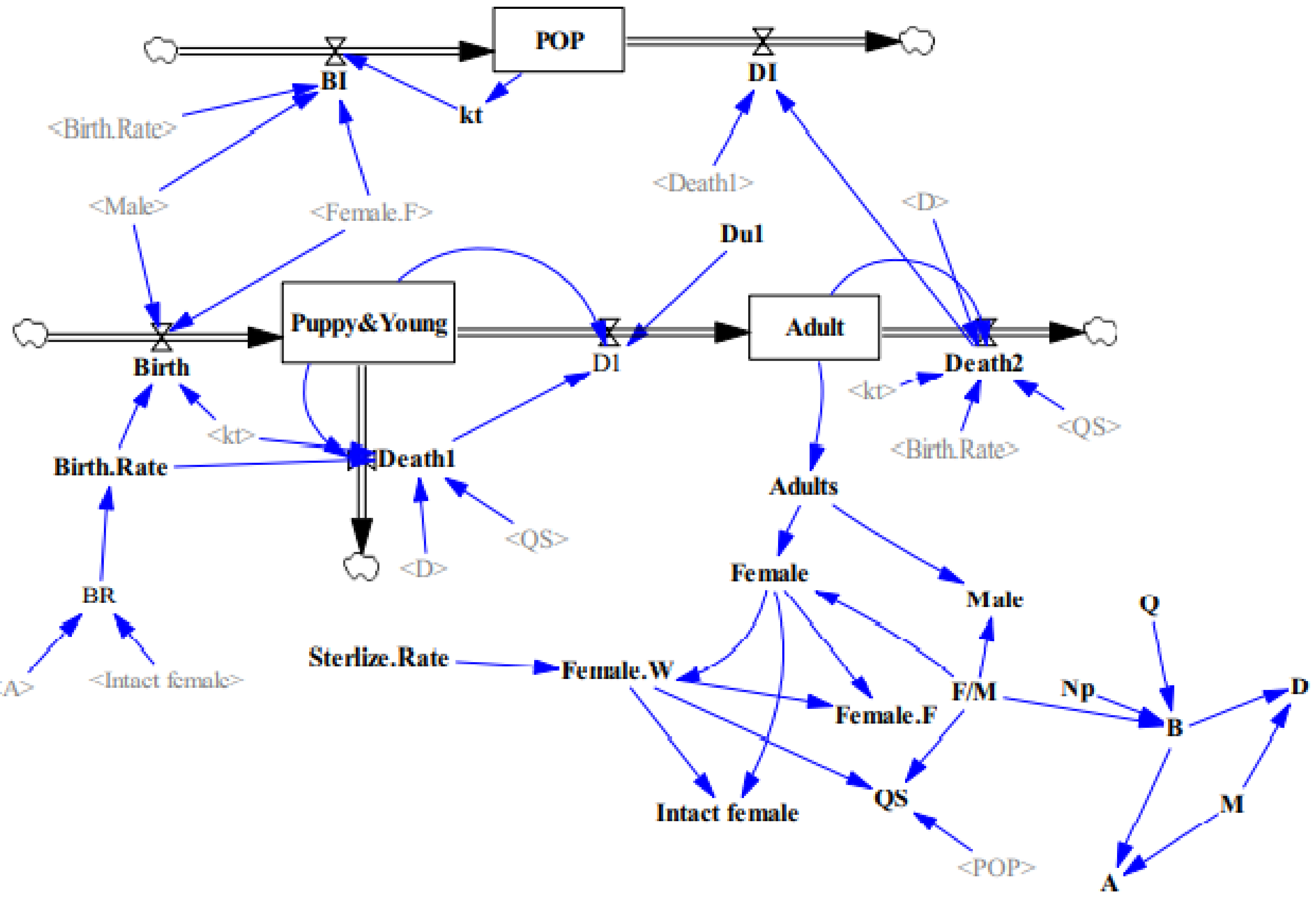
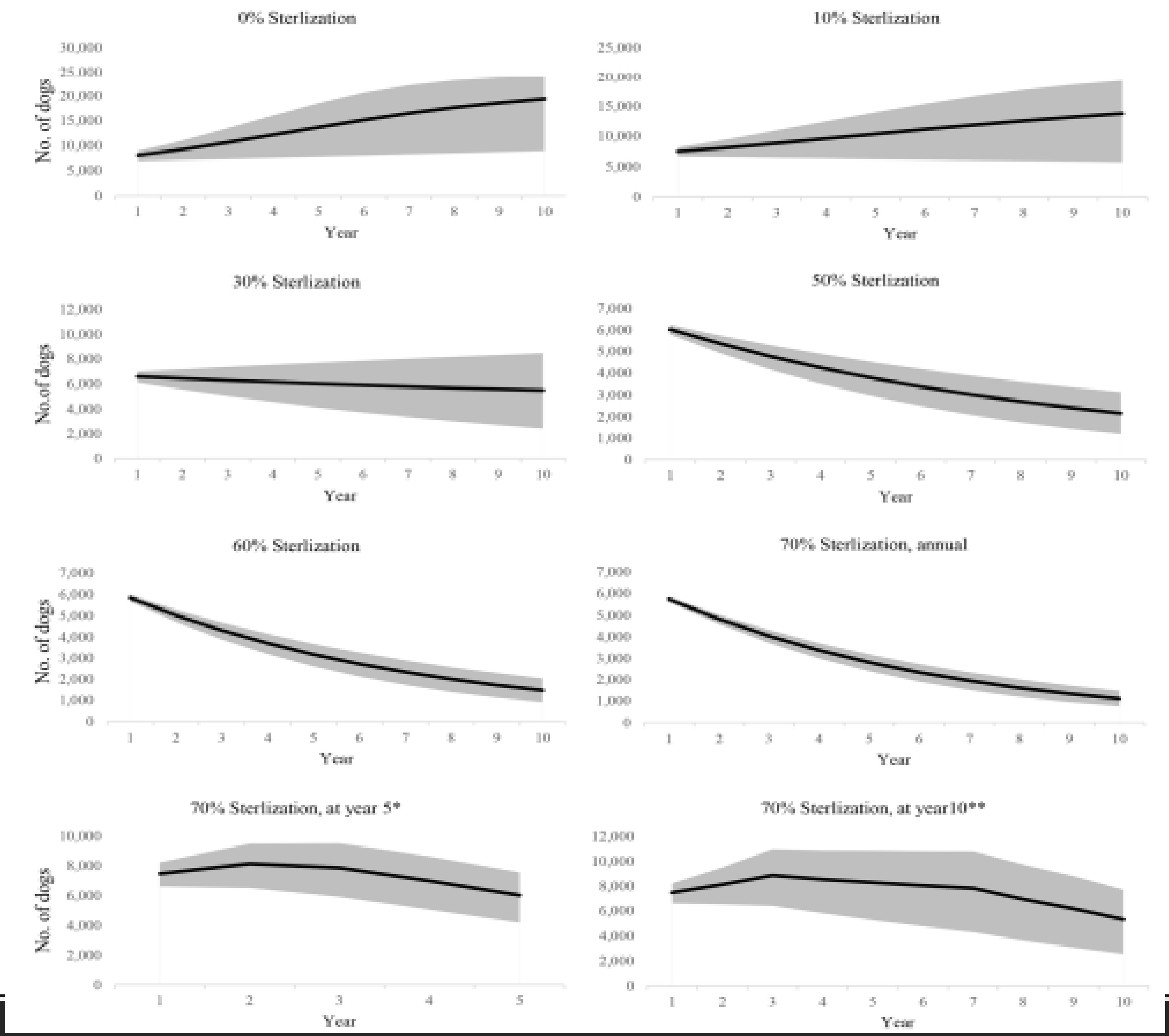



**Figure 5.** Model of the dynamics of dog population. Dynamic modeling of free-roaming dog population with implementation of animal birth control program.

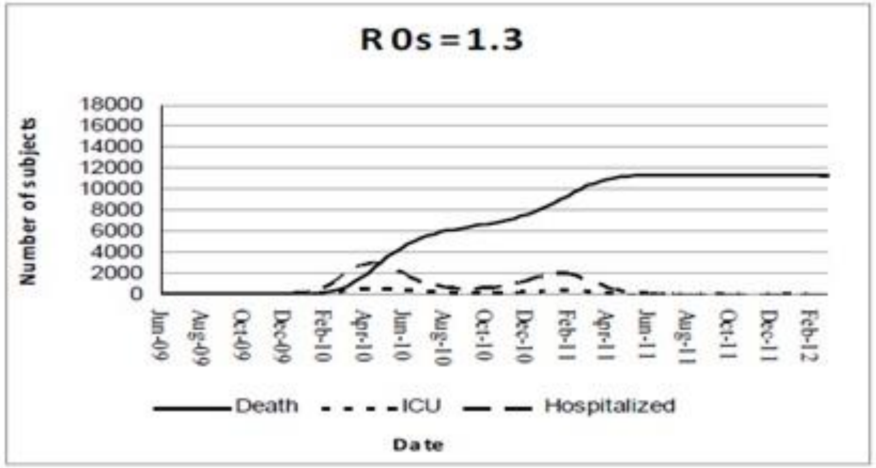


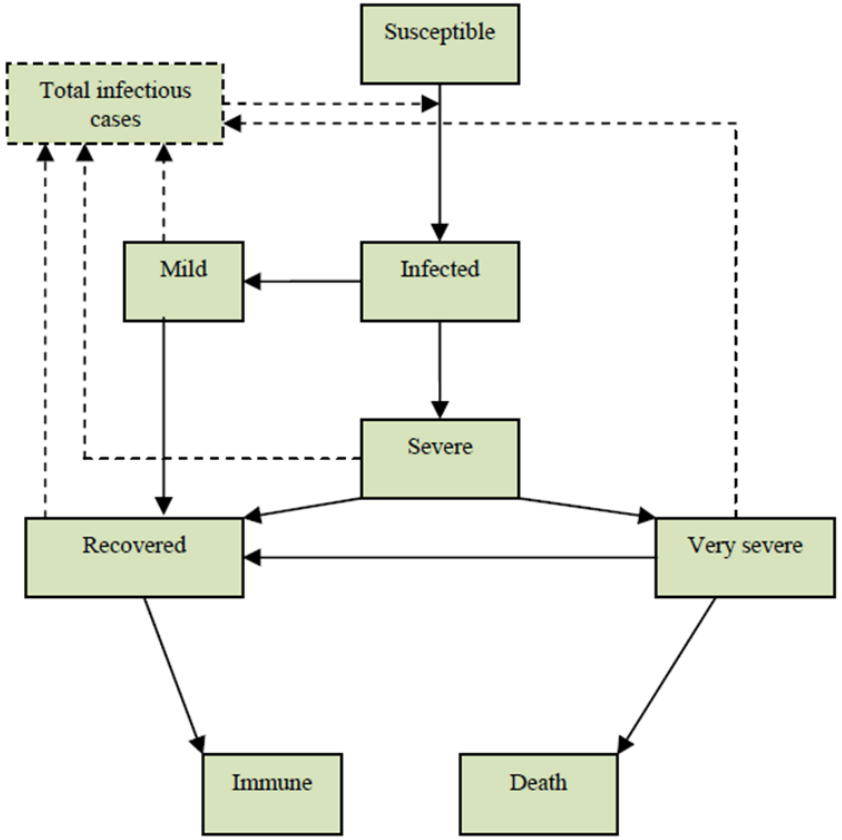

Dog population model predictions according to fve diferent scenarios of animal birth control in a 5- and 10-year intervention program (*Consistent spaying of dogs over 5 years so as to cover 70% of the females in the fnal year.
**Consistent spaying of dogs over 10 years so as to cover 70% of the females in the fnal year).

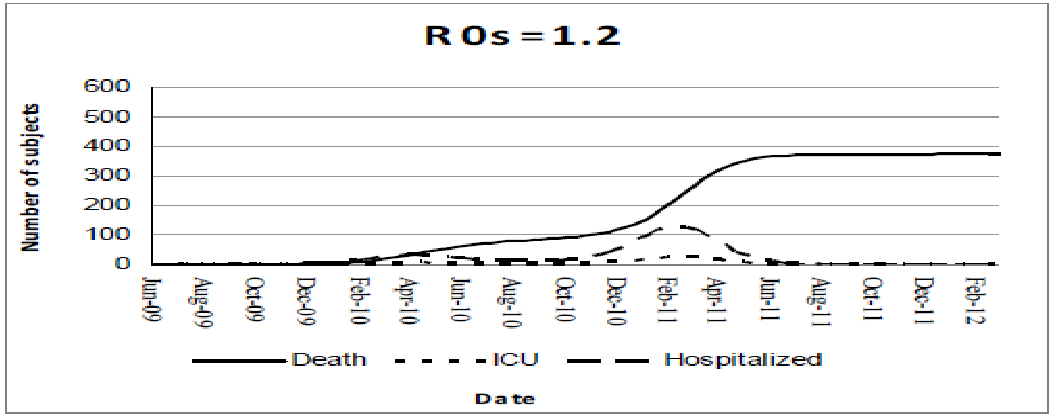
# Simple model for Influenzas in Iran

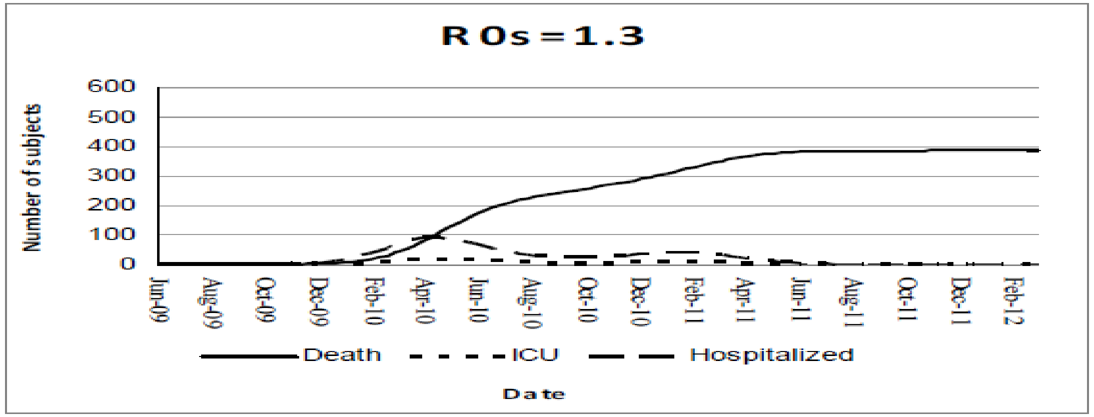
**Table 1.** Parameters used in the conceptual framework of influenza model

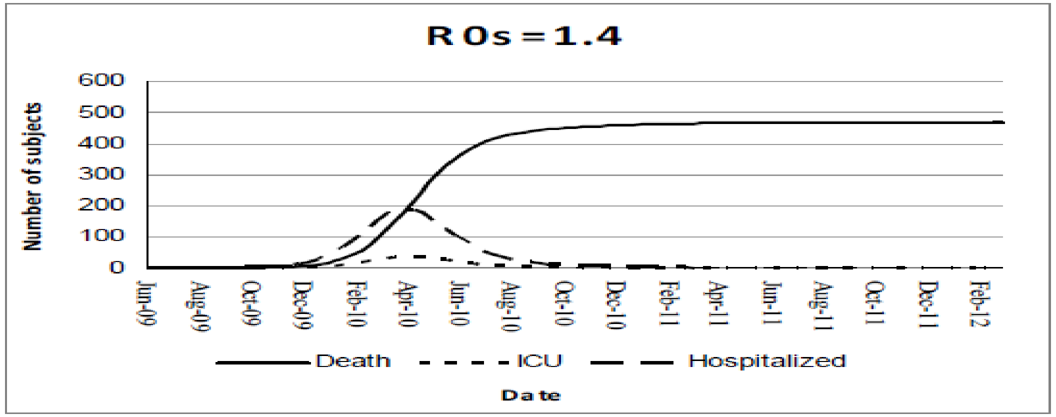
| Parameter | Value used | Reference |
|---|---|---|
| Latent period | 2 days | 1, 3 |
| Duration of infectivity | 7 days | 22 |
| Duration of moderate disease | 4 days | 1 |
| Duration of severe disease | 7 days | 11, 12 |
| Duration of recovery | 5 days | 23 |
| Percentages of asymptomatic or mild patients | 97% | 6, 12 – 13 |
| Percentages of severe patients | 3% | 6, 12 – 13 |
| Percentages of severe patients who needs ICU care | 20% | 6, 12 – 13 |
| Percentage of death among patients in ICU | 60% | 6, 12 – 13 |
| $R_0$ (in summer) | 1.2 ($R_{0sMin}$) up to 1.4 ($R_{0sMax}$) for Kerman<br>1.3 ($R_{0sMin}$) up to 1.5 ($R_{0sMax}$) for Tehran | 3, 13, 14, 16, 24, 25 |
| $R_0$ (in winter) | 1.6 for Kerman<br>1.8 for Tehran | 3, 13, 14,16, 26, 27 |

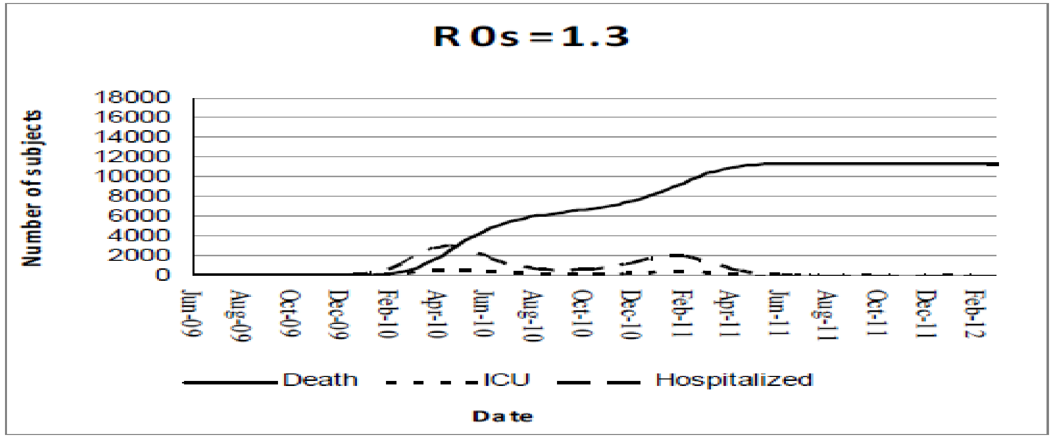


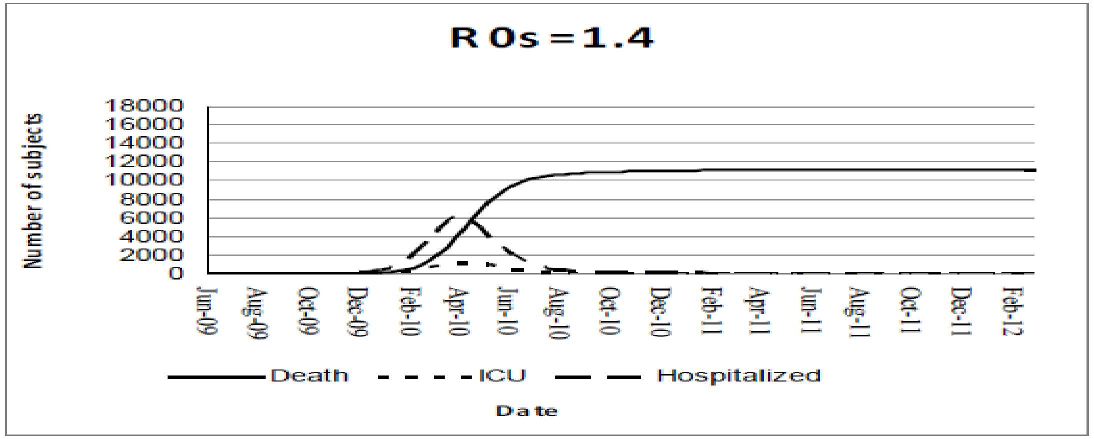



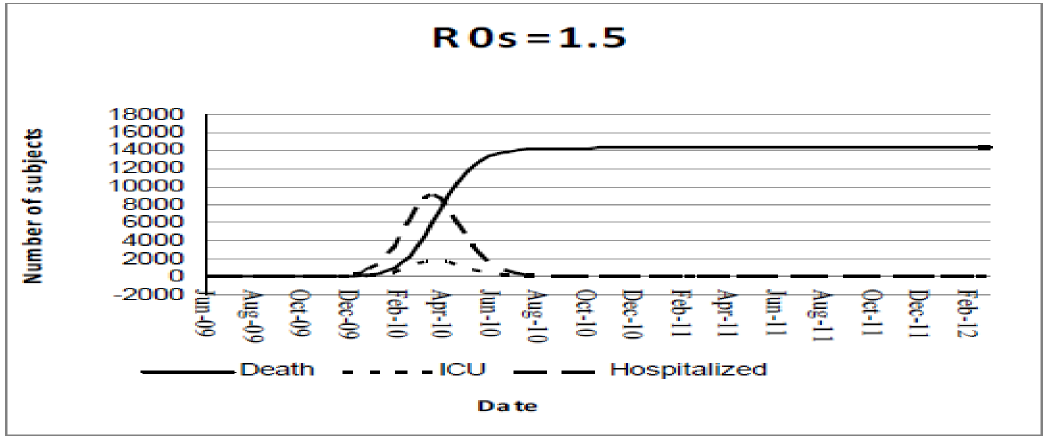

R 0s = 1.2
Number of subjects
600
500
400
300
200
100
0
Jun-09 Aug-09 Oct-09 Dec-09 Feb-10 Apr-10 Jun-10 Aug-10 Oct-10 Dec-10 Feb-11 Apr-11 Jun-11 Aug-11 Oct-11 Dec-11 Feb-12
Death
ICU
Hospitalized
Date


R 0s = 1.3
Number of subjects
600
500
400
300
200
100
0
Jun-09 Aug-09 Oct-09 Dec-09 Feb-10 Apr-10 Jun-10 Aug-10 Oct-10 Dec-10 Feb-11 Apr-11 Jun-11 Aug-11 Oct-11 Dec-11 Feb-12
Death
ICU
Hospitalized
Date


R 0s = 1.4
Number of subjects
600
500
400
300
200
100
0
Jun-09 Aug-09 Oct-09 Dec-09 Feb-10 Apr-10 Jun-10 Aug-10 Oct-10 Dec-10 Feb-11 Apr-11 Jun-11 Aug-11 Oct-11 Dec-11 Feb-12
Death
ICU
Hospitalized
Date


R 0s = 1.3
Number of subjects
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Jun-09 Aug-09 Oct-09 Dec-09 Feb-10 Apr-10 Jun-10 Aug-10 Oct-10 Dec-10 Feb-11 Apr-11 Jun-11 Aug-11 Oct-11 Dec-11 Feb-12
Death
ICU
Hospitalized
Date

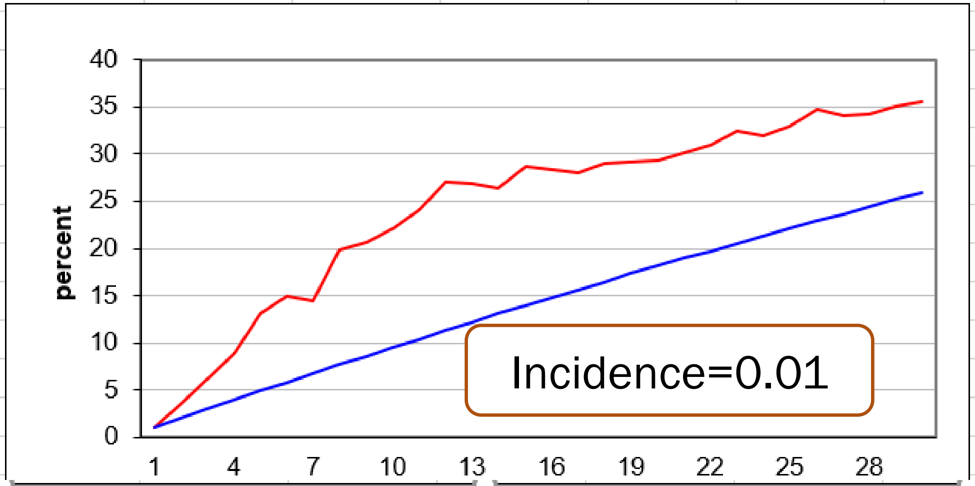

R 0s = 1.4
Number of subjects
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Jun-09 Aug-09 Oct-09 Dec-09 Feb-10 Apr-10 Jun-10 Aug-10 Oct-10 Dec-10 Feb-11 Apr-11 Jun-11 Aug-11 Oct-11 Dec-11 Feb-12
Death
ICU
Hospitalized
Date

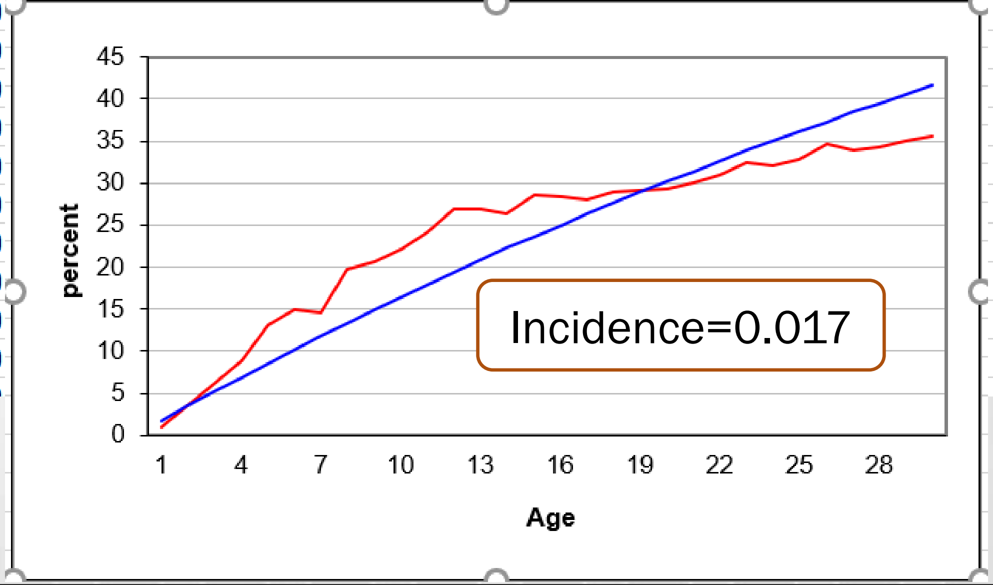

R 0s = 1.5
Number of subjects
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
-2000
Jun-09 Aug-09 Oct-09 Dec-09 Feb-10 Apr-10 Jun-10 Aug-10 Oct-10 Dec-10 Feb-11 Apr-11 Jun-11 Aug-11 Oct-11 Dec-11 Feb-12
Death
ICU
Hospitalized
Date

# Estimation of incidence rate of hepatitis

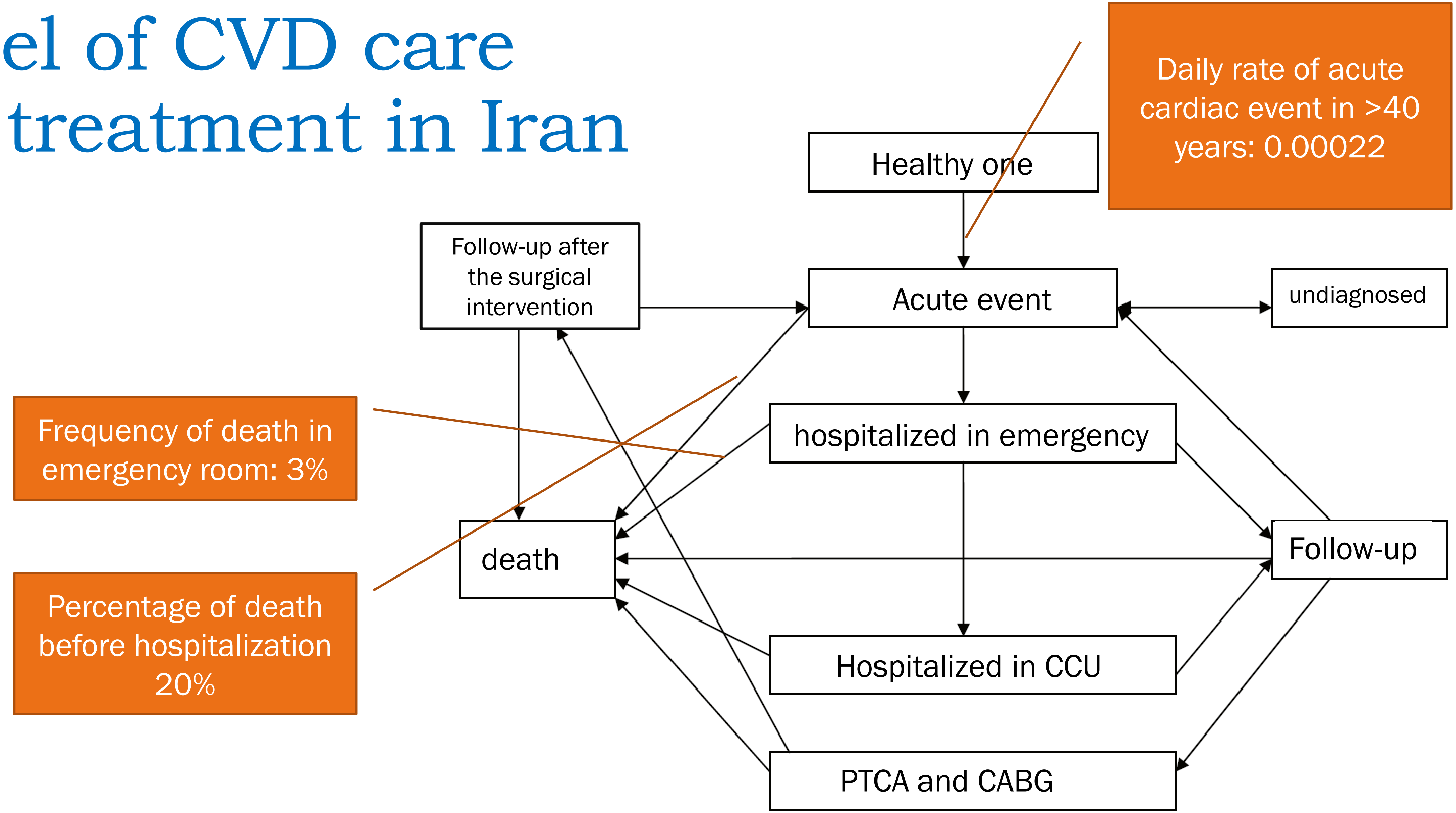
| Incidence | 0.01 |
|---|---|

| age | observed HBS-Ab(+) | estimated value | Diff | Diff2 |
|---|---|---|---|---|
| 1 | 0.997 | 0.995 | -0.002 | 0.000003933776060634 |
| 2 | 3.5 | 1.980 | -1.520 | 2.309996702854750000 |
| 3 | 6.1 | 2.955 | -3.145 | 9.888215801503520000 |
| 4 | 8.9 | 3.921 | -4.979 | 24.789882511028900000 |
| 5 | 13.2 | 4.877 | -8.323 | 69.271371027200500000 |
| 6 | 14.9 | 5.824 | -9.076 | 82.382005567662100000 |
| 7 | 14.5 | 6.761 | -7.739 | 59.898033596343600000 |
| 8 | 19.8 | 7.688 | -12.112 | 146.691693620475000000 |
| 9 | 20.7 | 8.607 | -12.093 | 146.243515711041000000 |
| 10 | 22.2 | 9.516 | -12.684 | 160.877306140287000000 |
| 11 | 24.1 | 10.417 | -13.683 | 187.235805823486000000 |
| 12 | 27 | 11.308 | -15.692 | 246.240234595034000000 |
| 13 | 26.9 | 12.190 | -14.710 | 216.370657977056000000 |
| 14 | 26.4 | 13.064 | -13.336 | 177.844189486833000000 |
| 15 | 28.6 | 13.929 | -14.671 | 215.232303467353000000 |
| 16 | 28.4 | 14.786 | -13.614 | 185.351312740763000000 |
| 17 | 28 | 15.634 | -12.366 | 152.929868638172000000 |
| 18 | 29 | 16.473 | -12.527 | 156.926258670248000000 |
| 19 | 29.1 | 17.304 | -11.796 | 139.143572806681000000 |
| 20 | 29.4 | 18.127 | -11.273 | 127.082226895289000000 |



# Model of CVD care and treatment in Iran



# The results of models in Iran in 2006

| Outputs of the model | numbers |
| --- | --- |
| Number of daily cardiac attacks in Iran | 5180 |
| Number of needed emergency beds for cardiac attacks | 23520 |
| Number of needed CCU beds | 8540 |
| Number of specialists to provide care to hospitalized cases | 2240 |
| ….. | |
| …… | |

# Common terms in dynamic models

In deterministic models, the output of the model is fully determined by the parameter values and the initial values, whereas probabilistic (or stochastic) models incorporate randomness in their approach.