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Risk Process Construction for Health Insurance

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Risk Process Construction for Health Insurance

The classical actuarial model for health insurance:

- the analysis of transitions between basic states 'healthy', 'sick' and 'dead‘
- the graph corresponded to treatment could be seen as a representation of the random process of the diagnostics and treatment
- Waters, 1984; Haberman and Pitacco, 1999

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The basic problems of the classical model:

- Simplification because of the deficit of information (lack of statistics etc.)
- Simplified structure of process (say, only three states)
- Assumption about the Markov property

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It is important for practical applications to construct more detailed models

But trying to safe the mathematical power of the Markov processes

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In health insurance field,

the model could be used for:

- specifying actuarial estimations,
- the adoption of underwriting,
- the analysis of claims policy,
- the risk management.

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Outside of health insurance field,

the model could be used for:

- the rationing of medical services,
- the treatment process management,
- the resources planning of the health care,
- the solution of malpractice problems.

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The basic problem:

how to construct risk process

Risk process = process of diagnostics and treatment

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In real life, the Markov property for any process of diagnostics and treatment is not fulfilled

- the probabilities/forces of the transition from state 'sick' depend on the duration of stay in that state
- the graph may contain a directed circuit

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A possible approach to achieve the Markov property is to aggregate the set of initial states into the set of aggregated states in order to reach an acceptable compromise between

- the adequacy of model,
- the sources of statistical data and
- the Markov process approach for modelling

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The necessary and sufficient conditions for such an aggregation are quite strong

Kemeny and Snell, 1960

not appropriate for practical situations

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Special procedure based on the interpretation of the random process:

aggregation and disaggregating the appropriate states

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Problems with the procedure:

- too sophisticated,
- not guarantee an automatic achievement of the Markov property,
- no easy to find the degree of aggregation.

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The aggregation

some initial states concerning to a particular sequence of diagnostic and treatment manipulations could be united in aggregated one

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The first example of disaggregating:

a graph with a directed circuit

Possibilities:

- different stages of the treatment
- the treatment of chronic diseases (repeated treatment)

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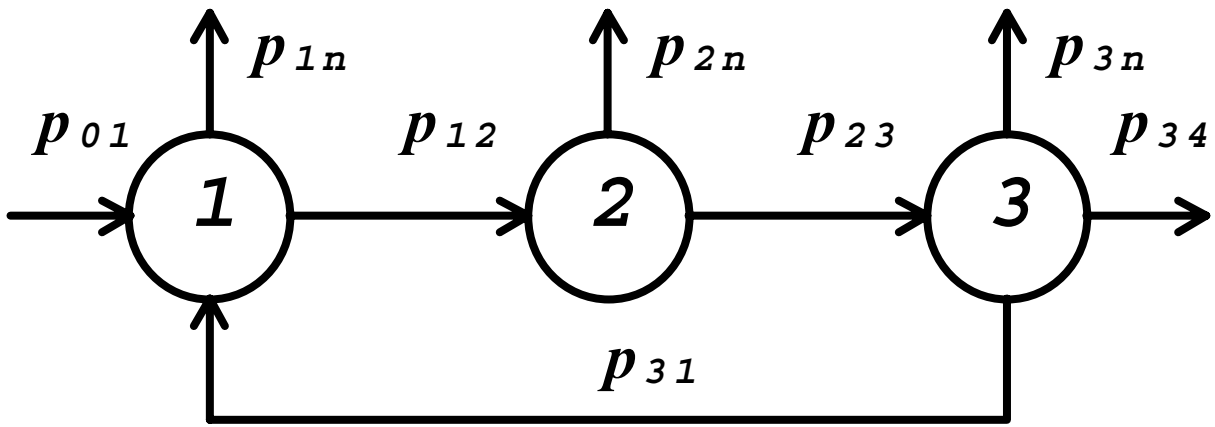
The graph before disaggregating



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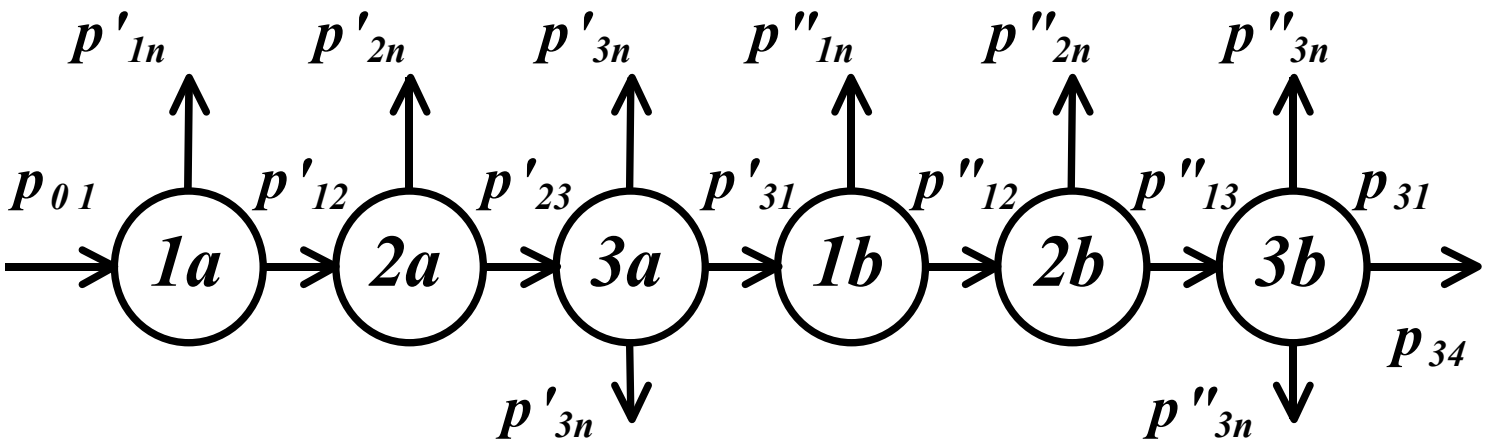
The graph after disaggregating



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Results:

- the graph transformed is more adequate
- it takes into account a number of reiterations of the specified group of services
- it allows, if necessary, to specify estimators for the probabilities of transition

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The second example of disaggregating:

the influence of the particular medical service to the probability distribution on consequent steps

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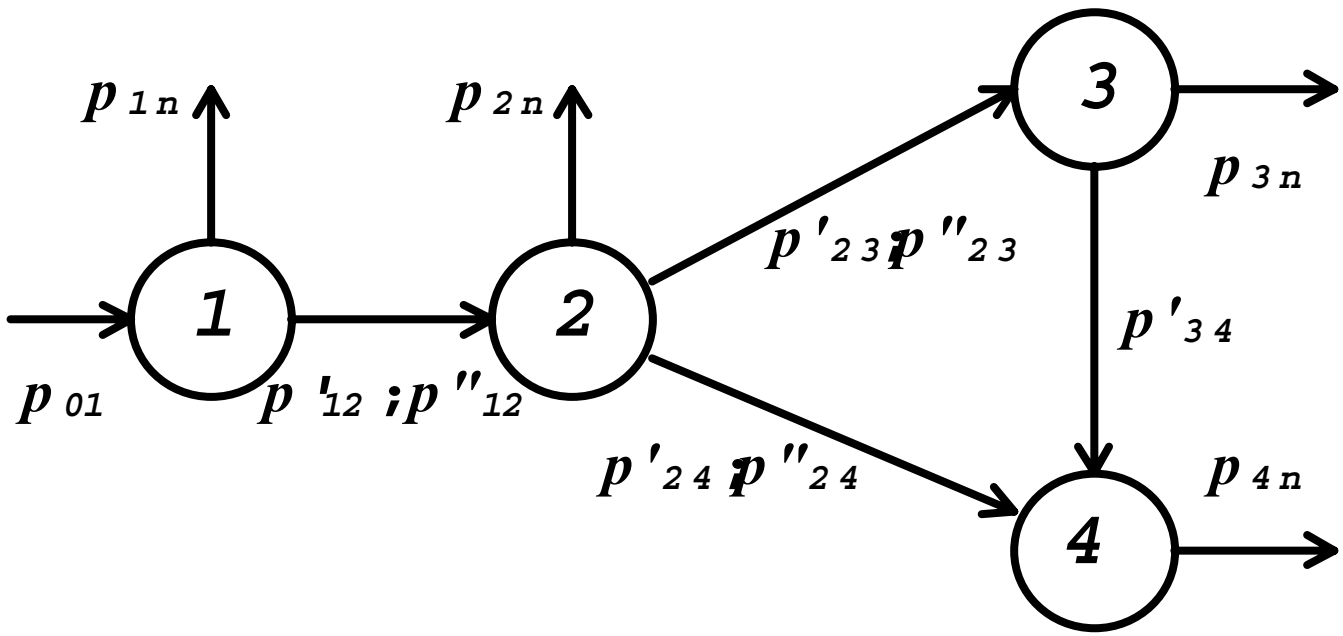
The graph before disaggregating



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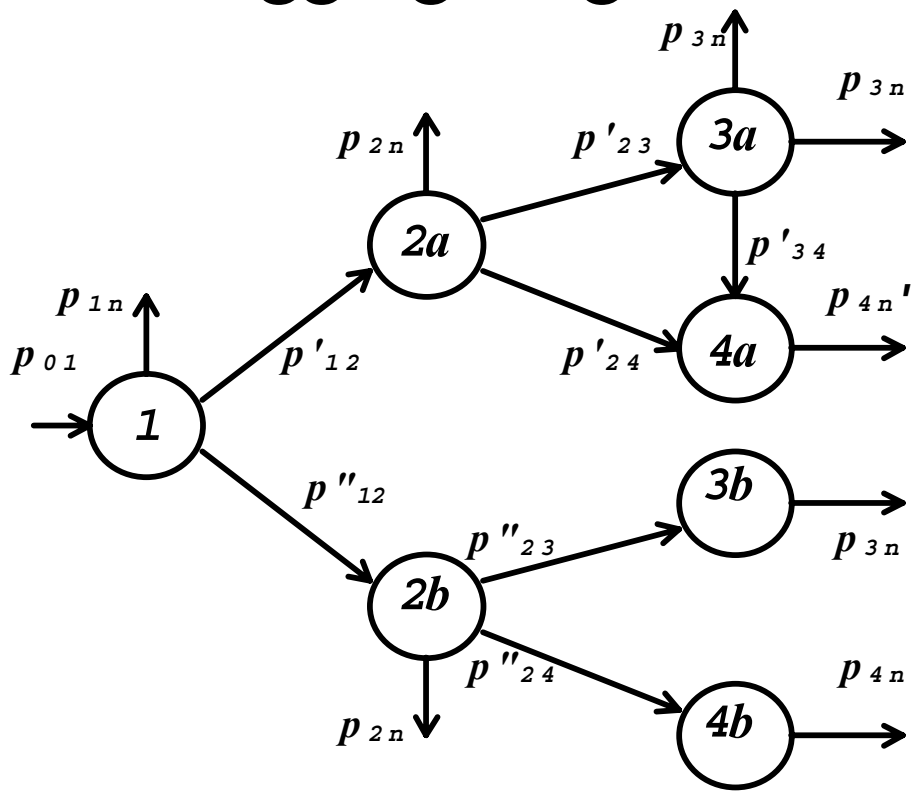
The graph after disaggregating



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An example of constructing the model

treatment process for acute cranial and cerebral trauma

in co-operation with the experts from St.Petersburg Medical Academy and Russian Neuro-Surgical Research Center named after Polenov

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The diagnostic and treatment process is highly aggregated for achieving the Markov property

14 states represent

- the inception of trauma (state 1)
- treatment in particular hospitals or medical services provided by the particular institutions (states 2 to 11)
- the outcomes of treatment (states 12 to 14)

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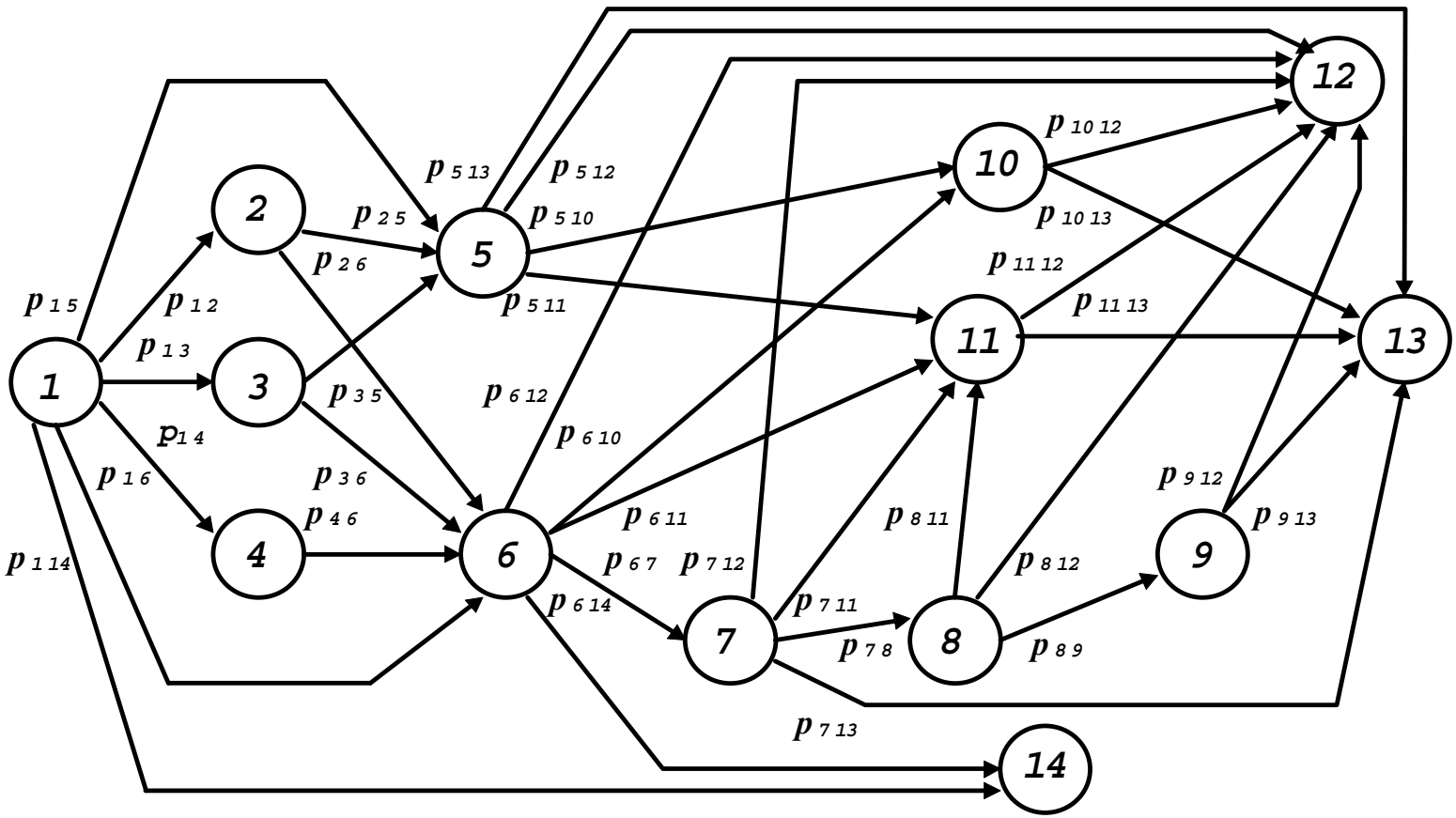

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1 - the inception of trauma;

2 - first aid provided by special traumato-logical out-patient hospital;

3 - first aid provided by in-patient hospital;

4 - first aid provided by ambulance;

5 - out-patient treatment;

6 - in-patient treatment: 1st hospitalisation;

7 - out-patient treatment;

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8 - in-patient treatment: repeated hospitalisation;

9 - out-patient treatment;

10 - rehabilitating in-patient treatment;

11 - rehabilitating out-patient treatment;

12 - practically healthy;

13 - permanently disabled;

14 - dead.

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The matrix of the probabilities of transition:

$$
\left(\begin{array}{ccccccccccc|ccc}
0 & p_{12} & p_{13} & p_{14} & p_{15} & p_{16} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & p_{114} \\
0 & 0 & 0 & 0 & p_{25} & p_{26} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & p_{35} & p_{36} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & p_{46} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & p_{5\,10} & p_{5\,11} & p_{5\,12} & p_{5\,13} & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & p_{67} & 0 & 0 & p_{6\,10} & p_{6\,11} & p_{6\,12} & p_{6\,13} & p_{6\,14} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & p_{78} & 0 & 0 & p_{7\,11} & p_{7\,12} & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & p_{89} & 0 & p_{8\,11} & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & p_{9\,12} & p_{9\,13} & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & p_{10\,12} & p_{10\,13} & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & p_{11\,12} & p_{11\,13} & 0 \\
\hline
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1
\end{array}\right)
$$

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using such a matrix for

- the evaluation of some characteristics (say, the probability of treatment into the particular type of hospitals)
- the comparison of real and ideal probabilities for the evaluation of the treatment quality
- analysis of how the diagnostic errors may influence on the treatment process

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Stability of probability estimators

and, hence, the risk process

It is a key problem of the risk process construction for health insurance

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Example

- simplified diagnostic and treatment process for acute cranial and cerebral trauma
- data set: the first aid at children's acute cranial and cerebral trauma for one district of St.Petersburg in 1987 and 1994

  (In 1987, the mortality, morbidity and economic situation was rather stable; in 1994, it was the worst for some last decades)

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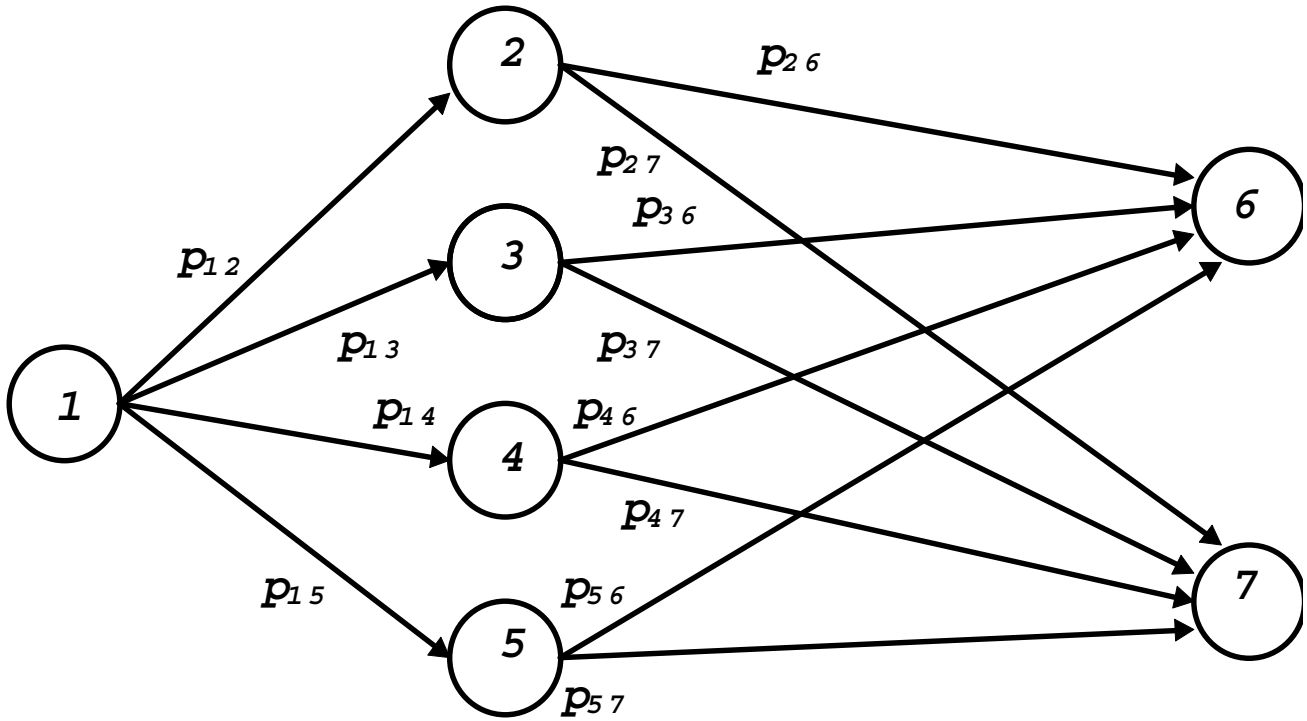
simplified diagnostic and treatment process



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Legend:

1 - the inception of trauma;

2 - first aid provided by special traumato-logical out-patient hospital;

3 - first aid provided by ambulance;

4 - first aid provided by out-patient children's hospital;

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5 - first aid provided by other types of medical institutions;

6 - in-patient treatment;

7 - out-patient treatment

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The probabilities of transition for 1987:

0,0000	*0,2222*	*0,5937*	*0,0825*	*0,1016*	*0,0000*	*0,0000*
0,0000	*0,0000*	*0,0000*	*0,0000*	*0,0000*	*0,4500*	*0,5500*
0,0000	*0,0000*	*0,0000*	*0,0000*	*0,0000*	*0,6043*	*0,3957*
0,0000	*0,0000*	*0,0000*	*0,0000*	*0,0000*	*0,7116*	*0,2884*
0,0000	*0,0000*	*0,0000*	*0,0000*	*0,0000*	*0,5156*	*0,4844*
0,0000	*0,0000*	*0,0000*	*0,0000*	*0,0000*	*1,0000*	*0,0000*
0,0000	*0,0000*	*0,0000*	*0,0000*	*0,0000*	*0,0000*	*1,0000*

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The probabilities of transition for 1994:

0,0000	*0,2620*	*0,5599*	*0,0808*	*0,0973*	*0,0000*	*0,0000*
0,0000	*0,0000*	*0,0000*	*0,0000*	*0,0000*	*0,4800*	*0,5200*
0,0000	*0,0000*	*0,0000*	*0,0000*	*0,0000*	*0,7781*	*0,2219*
0,0000	*0,0000*	*0,0000*	*0,0000*	*0,0000*	*0,7778*	*0,2222*
0,0000	*0,0000*	*0,0000*	*0,0000*	*0,0000*	*0,5077*	*0,4923*
0,0000	*0,0000*	*0,0000*	*0,0000*	*0,0000*	*1,0000*	*0,0000*
0,0000	*0,0000*	*0,0000*	*0,0000*	*0,0000*	*0,0000*	*1,0000*

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Comparison between (non-zero and non-unit) probabilities of transition in 1987 and 1994 using chi-square test (Kanji, 1993)

No. of Row	Empirical value	Critical value	Accept (+) or reject (–)?
1	2,82	7,81	+
2	26,46	3,84	–
3	0,28	3,84	+
4	0,61	3,84	+
5	0,01	3,84	+

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Results:

- the figures are rather close to each other
- excluding only the first aid provided by special traumatological out-patient hospital (but the role of it in public health care system in Russia had been changed for that period)

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Additional fluctuations of the probabilities of transition

Reasons:

- observational biases (selection),
- registration errors,
- seasonal changes etc.

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The first approach to model:

the assumption about multinomial distribution for each row of the matrix of the probabilities of transition

could be too formal.

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The second approach to model:

the estimation of the (sample) variations of probabilities from data observed

strong dependence of experience

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Example

- a bit more complicated version of the model based on 1987 data
- statistics were divided by 1-month period sets. Estimators for different months were different from each other

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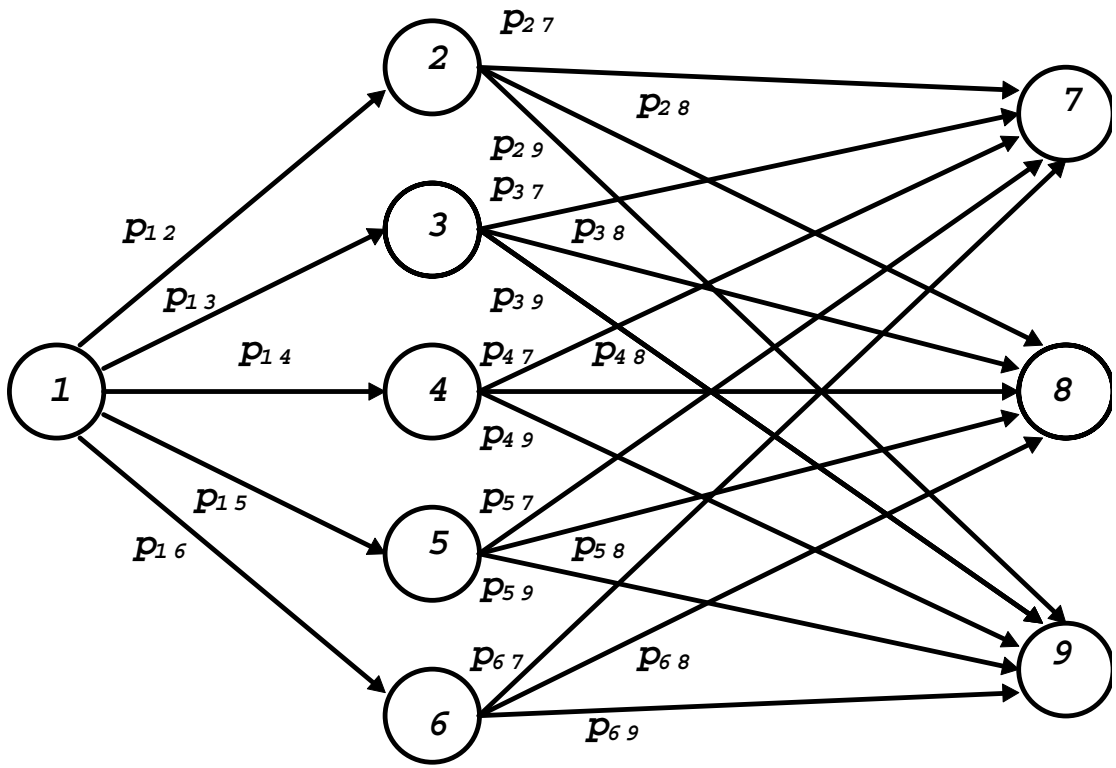
simplified diagnostic and treatment process



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5 - first aid provided by out-patient children's hospital;

6 - first aid provided by other types of medical institutions;

7 - in-patient treatment;

8 - out-patient treatment;

9 - out-patient treatment in special traumatological out-patient hospital.

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The (mean) probabilities of transition

0,000	*0,590*	*0,028*	*0,284*	*0,042*	*0,054*	*0,000*	*0,000*	*0,000*
0,000	*0,000*	*0,000*	*0,000*	*0,000*	*0,000*	*0,071*	*0,087*	*0,842*
0,000	*0,000*	*0,000*	*0,000*	*0,000*	*0,000*	*0,381*	*0,548*	*0,072*
0,000	*0,000*	*0,000*	*0,000*	*0,000*	*0,000*	*0,530*	*0,348*	*0,122*
0,000	*0,000*	*0,000*	*0,000*	*0,000*	*0,000*	*0,587*	*0,238*	*0,175*
0,000	*0,000*	*0,000*	*0,000*	*0,000*	*0,000*	*0,240*	*0,181*	*0,579*
0,000	*0,000*	*0,000*	*0,000*	*0,000*	*0,000*	*1,000*	*0,000*	*0,000*
0,000	*0,000*	*0,000*	*0,000*	*0,000*	*0,000*	*0,000*	*1,000*	*0,000*
0,000	*0,000*	*0,000*	*0,000*	*0,000*	*0,000*	*0,000*	*0,000*	*1,000*

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Variation estimates for probabilities which are not equal to 0 or 1

State	Row 1	Column 7	Column 8	Column 9
2	0,004090	0,001093	0,001671	0,002975
3	0,000268	0,068764	0,080669	0,030612
4	0,001340	0,009164	0,009042	0,002688
5	0,000108	0,078622	0,047940	0,019646
6	0,000693	0,040871	0,013091	0,043340

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The development of the model:

- The research of the standardisation of treatment processes
- The investigation of the costs of treatment
- The construction of models based on controlled Markov processes
- Modelling a net of queuing systems

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Deeper research of the standardisation of any diagnostic and treatment processes

Different kinds of the diagnostic and treatment processes should be tested and investigated.

It is more biomedical research than economic or actuarial one

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The investigation of the costs of treatment

The model allows to look into those costs as an relatively separate process which is important because of data collecting

The model could be involved in the managed care policy

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The construction of models based on controlled Markov processes

Could be used for the solution of the problem of the choice of diagnostic and treatment methods

For comparisons with more expensive, but more effective medical services

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Modelling a net of queuing systems

Each node of the net is a server (a separate queuing system)

Allows to analyse risk process on the generalized level

Makes the model more adequate