COMPETING FOR NEW HOSPITAL LOCATIONS: A SIMULATION MODELING APPROACH

Abstract: *Hospitals compete with each other for patients and medical service offerings in much the same way as other types of businesses. Not all patients go to the hospital nearest to their homes due to brand name perceptions or association with a specific physician. However, some patient migration occurs between affiliated hospitals, because of a need for special services. This represents a complex competitive environment among hospitals which can be viewed positively or negatively. The negative manner means real competition for a relatively small local community, but the positive manner means the 'partnership' of hospitals to take advantage of size, centralization, expertise, and sophisticated medical specialties which require a critical mass of activity to be effective.. In a consolidating, competitive environment requiring fewer hospital beds and expensive facilities some hospitals do not wish to compete with each other, but rather cooperate by forming hospital partnerships or oligopolies. In this constrained environment modelling or optimization effort must consider both the positive and negative ramifications of competition along with the influence of natural boundaries (such as water features and bridges that separate communities) while seeking to find strategic opportunities to serve the communities in need of Health Care Services.*

Keywords: *health care, hospitals, competitive environment, simulation, model, program, decision making*

1. INTRODUCTION

Hospitals compete with each other for patients and medical service offerings in much the same way as other types of businesses. Not all patients go to the hospital nearest to their homes due to brand name perceptions or association with a specific physician. However, some patient migration occurs between affiliated hospitals, because of a need for special services. This represents a complex completive environment among hospitals which can be viewed positively or negatively. The negative manner means real competition for a relatively small local community, but the positive manner means the 'partnership' of hospitals that take advantage of size, centralization, expertise, and sophisticated medical specialties which require a critical mass of activity to be effective.. In a consolidating, competitive environment requiring fewer hospital beds and expensive facilities some hospitals do not wish to compete with each other, but rather cooperate by forming hospital partnerships or oligopolies. In this constrained environment a modelling or optimization effort must consider both the positive and negative ramifications of competition along with the influence of natural boundaries (such as water features and bridges that separate communities) while seeking to find strategic opportunities to serve the communities in need of Health Care Services. A special situation can be described in which a ‘Network' of three hospitals with common ownership want to establish a new hospital in their extended territory that will draw patients from nearby competing hospitals. This new hospital must minimize the draw or cannibalization of patients away from the two friendly hospitals while maximizing patients the draw from competitors. In practice there are often some other deterrents for patients to cross even though the hospital is nearby. These include river basins, major highways and mountain ranges although road systems and bridges may provide connectivity. There can be breakdowns by service such as medical, surgical, psychiatry, maternity and further product breakdowns by product such as cardiac, liver, lung, bones etc. This multiplies the dimensions of the problem by many orders of magnitude and ultimately involves regulatory constraints and traditional marketing opportunities.

A simple simulation model is described for use by hospital planners. The model simulates the dynamic phenomena and it is very flexible for the set up of conditions, restrictions and obstacles which may be encountered. The suggested program enables the simulation of the problem as described and its results are expected to improve the quality of the decision-making process.

2. THEORY

Two dimensional partial differential equations of second order is used for simulation for mentioned problem in the form

$$\frac{\partial D}{\partial t} = K_x \frac{\partial^2 D}{\partial x^2} + K_y \frac{\partial^2 D}{\partial y^2}.$$

The equation is in a differential form [Dostál 2008]

$$D_{t+1,i,j} = D_{t,i,j} + K\left[K_x\left(D_{t,i,j-1} - 2D_{t,i,j} + D_{t,i,j+1}\right) + K_y\left(D_{t,i+1,j} - 2D_{t,i,j} + D_{t,i-1,j}\right)\right]$$

where $K = \frac{\nabla t}{(\nabla x)^2}$.

3. BUILD OF THE MODEL

The meaning of used variables in competitive environment model is as follows: The values of "cells" of competitive environment $D_{t,i,j}$ with index of time *t* and system of coordinates *i, j* are presented by the range from *+100%* to *0%*, where *+100%* means the maximum capacity of the use of hospital (capacity utilization) and *0%* means the zero capacity of the use of hospital (for example when the new hospital is build). The various conditions of hospitals create the competitive environment. The value K is a simulation constant. The constants K_x and K_y present the rate of 'resistance' of competition environment in direction of *x* and *y*. Each cell $\boldsymbol{O}_{i,j}$ is coded in the following manner:

a) any influence on competitive environment (except initial condition),
b) solid obstacle (obstacle for competitive environment),
c) positive and constant influence on competitive environment,
d) positive and variable influence on competitive environment,
e) negative and constant influence on competitive environment,
f) negative and variable influence on competitive environment.

The program was designed for the simulation of the competitive environment. The input values are constants K, K_x, K_y, matrix $\boldsymbol{D}_{0,i,j}$*(n x m)* (initial conditions *D* of competitive environment of each cell in time $T_0 = 0$), matrix $\boldsymbol{O}$*(n x m)* (code of each cell). The last item is the time T_{end}, the end time of calculation of competitive environment. This problem is solved in [Dostál 2008].

4. REAL CASE

The real case presents the situation of hospital competitive environment presented among hospitals in New York State (see fig.1).

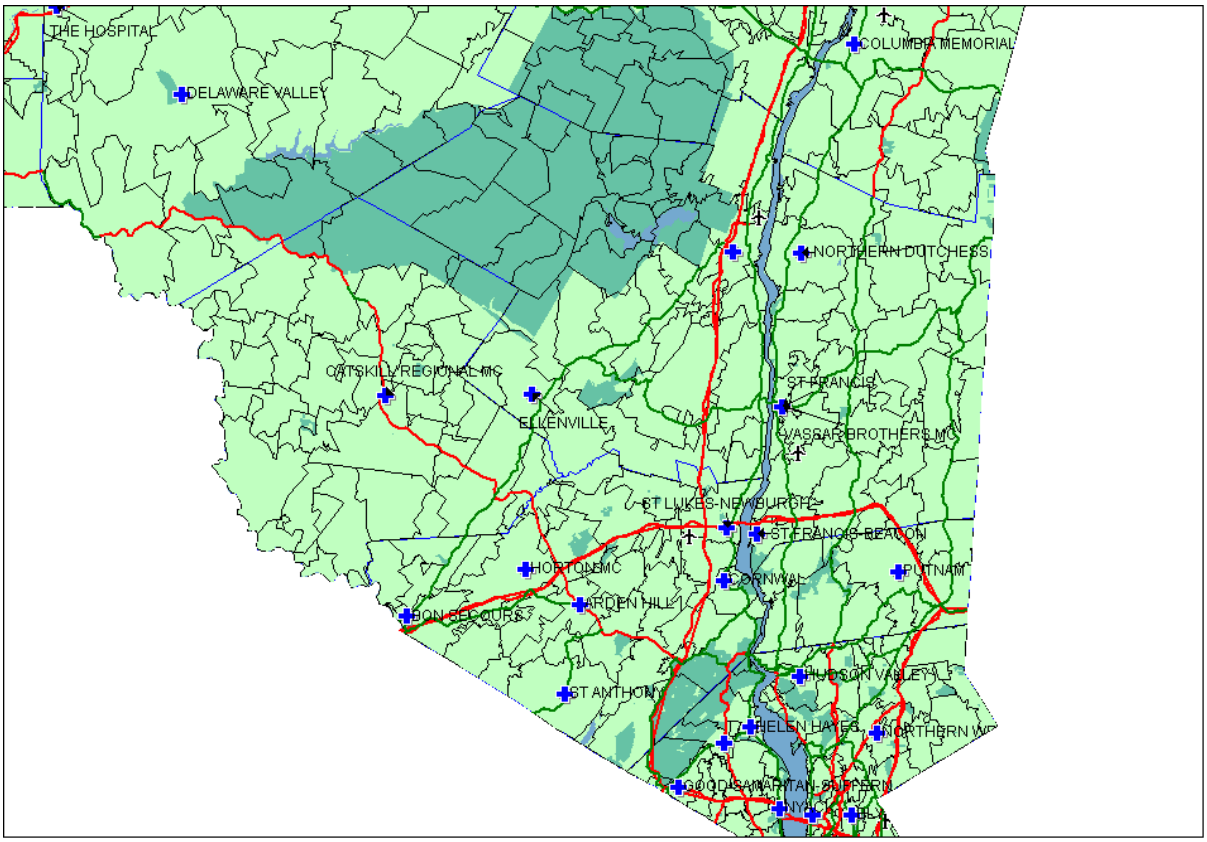

Fig.1 The places of hospitals

The name of hospitals are marked by number *1a, 1b, 1c, 2, 3, 4, 5, 6, 7, 8, 9, 10* (see fig.2) and authors knows their names.

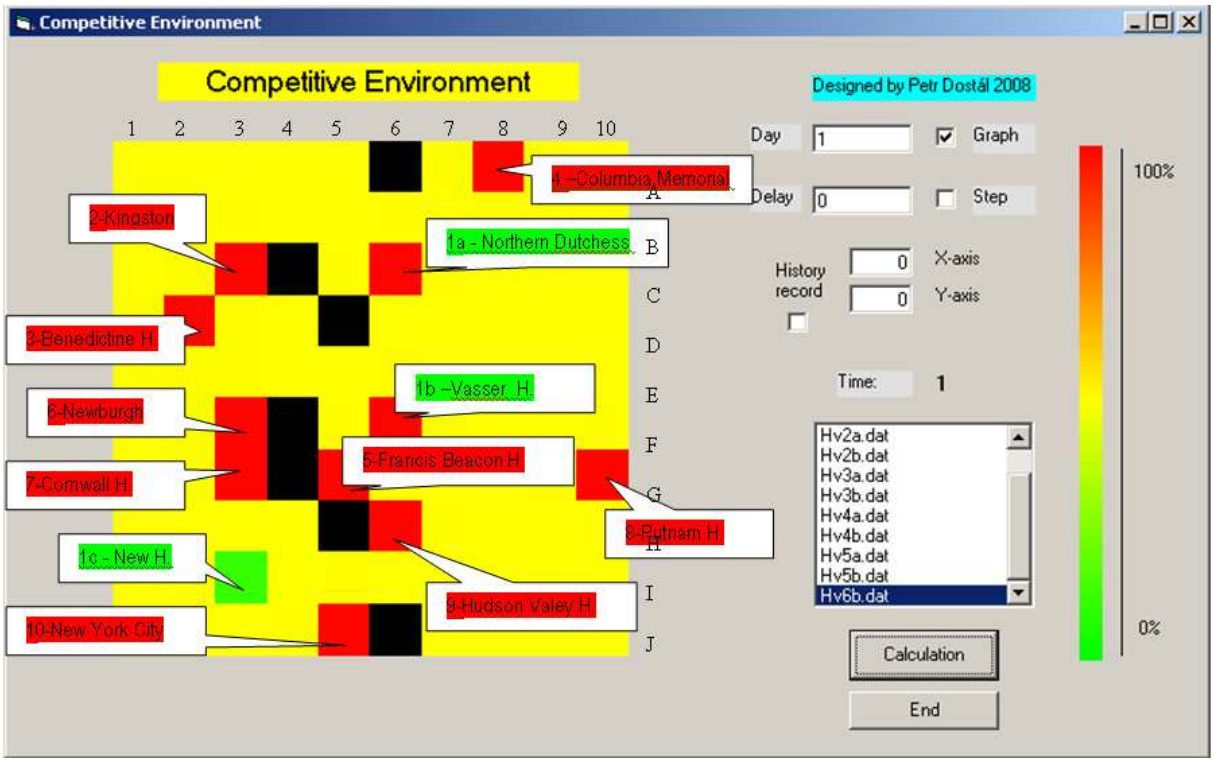

Fig.2 The placement of hospitals

The fig. 2 presents mentioned situation when the 'partnership' hospitals 1a) and 1b, want to establish a new hospital 1c) in their territory (green label) that will draw patients from nearby competing hospitals. The new

hospital 1c) must minimize the draw away patients from the two friendly hospitals 1a) and 1c) while to maximizing patients draw from competitors *2, 3, 4, 5, 6, 7, 8, 9, 10* (red label). There where simulated various sectors where to build up a new hospital such as E3, I3, D9, I9 etc in a grid 10x10 cells. The best solution represented by the placement of new hospital in I3 sector (from the point of draw away patients from two friendly hospitals and vice versa) is simulated.

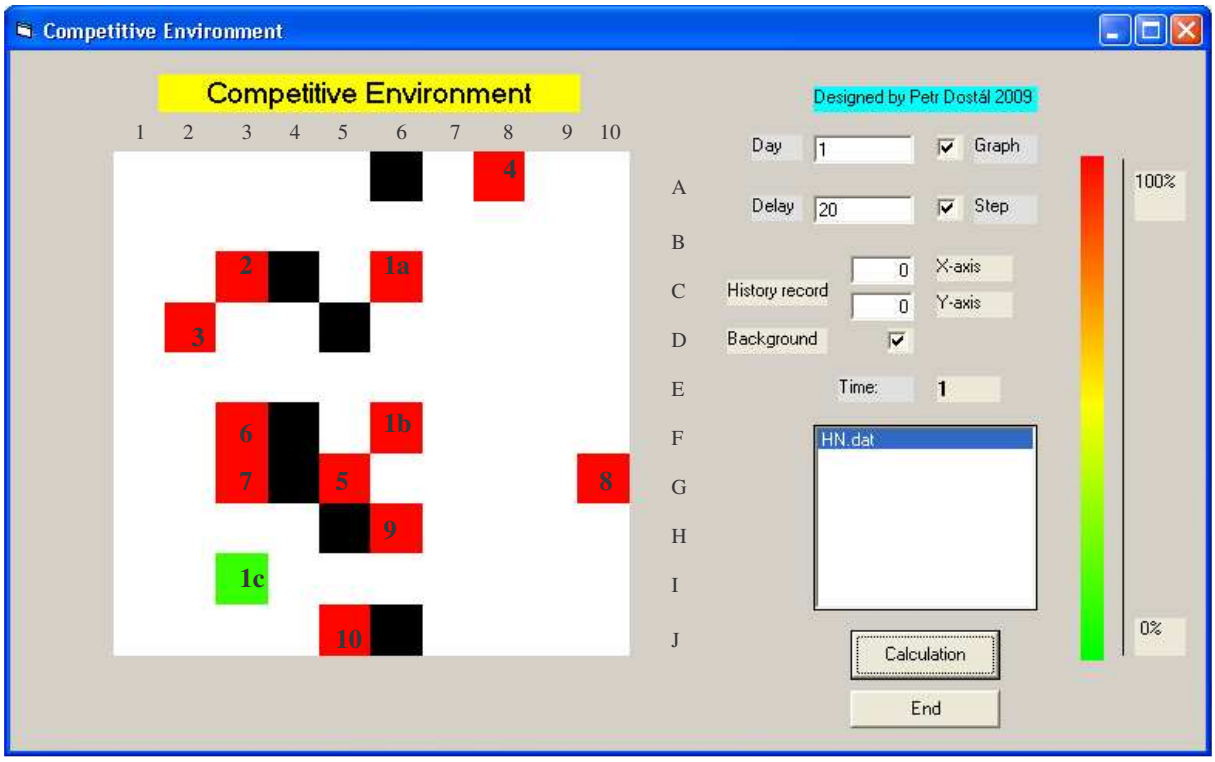

Fig.3 The initial situation of simulation

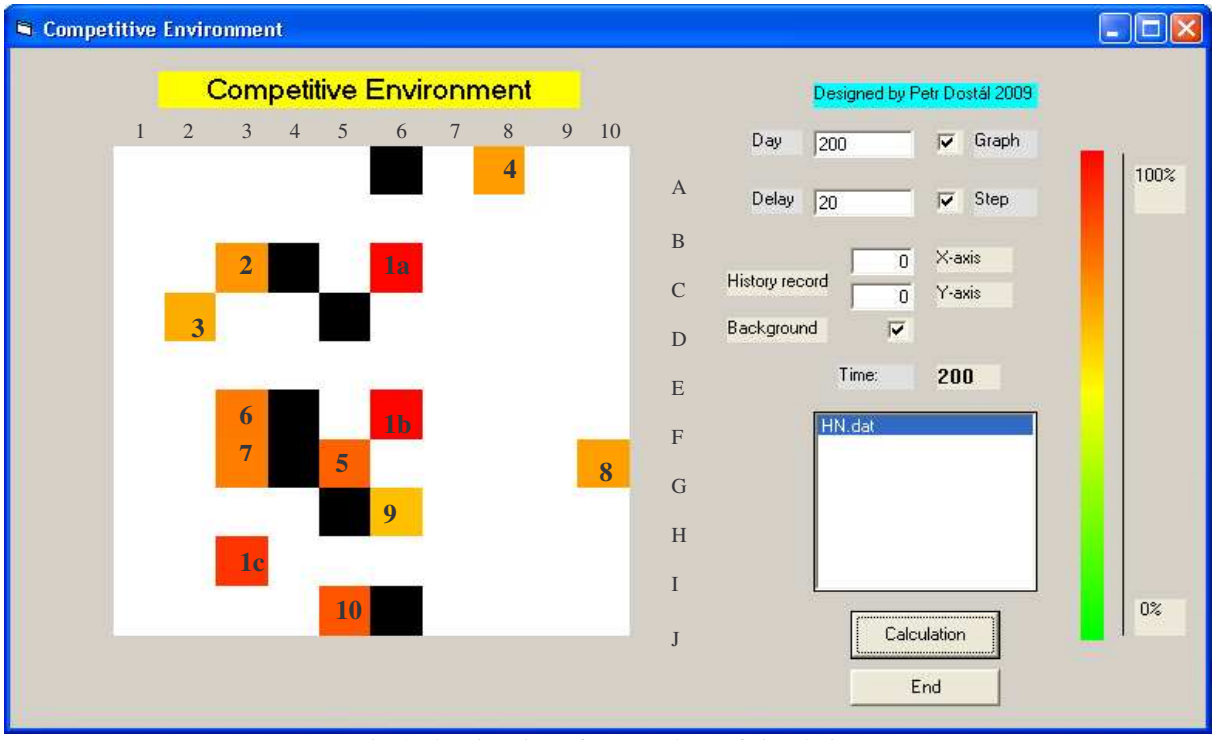

Fig.4 The situation after 200 days of simulation

The fig. 3 represents the initial situation in time $T = 1$ (first day). The red colour of hospitals represents the capacity of the use hospitals (the initial values are in the range from 90% to 100% and they correspond the reality). The new build up hospital has the zero 0% use of capacity that is represented by green colour. The black sectors represent the obstacles caused by river Hudson that place certain role in competition.

The fig. 4 represents the situation in time $T = 200$ (after 200 days). The orange colour of hospitals represents the capacity of the use hospitals (the values are in the range from 70% to 85% and they correspond to simulation). The red colour of hospitals represents the capacity of the use hospitals (the values are in the range from 85% to 100% and they correspond to simulation). The conclusion is that the new build up hospital 1c and 'partnership' hospitals 1a) and 1b, have the higher capacity of the use of hospital then the competing hospitals *2, 3, 4, 5, 6, 7, 8, 9, 10*. The simulation of build up of a new hospital in sectors E3, D9, I9 gives the worse results for 'partnership' ones.

The designed model is simple one and it will be in future detailed by the use of grid 100x100 cells and more conditions will be included in solution such as the changes of public and transport availabilities by construction of new routes, parking places, local transport, new building and housing estates etc, together with the influence of attitude of patients which hospital to visit, quality of health care, good reputation of hospitals, recommendation of doctors etc. The authors handle with such data and the further research will be focused on data mining to make the model more precise to improve the quality of decision making of hospital planners. The simulation of breakdown by service such as medical, surgical, psychiatry, maternity etc., breakdown by product such as cardiac, liver, lung, bones etc will be done. It means to 'increase' the distance by some offers, regulations or restrictions.

5. CONCLUSION

The mentioned designed model is focused on the field of hospital competition environment. This method of the build up of a model and its realization by suggested program enables the search for hospital competitive environment that could be very important and its results can be used for decision making processes. The calculation can prevent losses. The designed method can be used not only for hospital competitive environment by also for example for the field of markets, banks, firms, supplier-customer relations etc.