SYSTEM DYNAMICS IN ACTION:

THE WORSE-BEFORE-BETTER SCENARIO IN THE CITY HOSPITAL - EFFECTS OF BUDGET DISTRIBUTION TO THE TRAINING & EDUCATION DEPARTMENT ON SHORT-TERM AND LONG-TERM PROFITS

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ABSTRACT

A major public city hospital is affected by the ongoing transformation in the Swiss health care system due to cost reduction pressure, mergers & acquisitions and the mandatory introduction of Diagnosis Related Groups (DRG) by the year 2012. Facing scarce financial and personal recourses, a System Dynamics research project investigates how changes in budget allocation to the training and education department can affect the net profits of the hospital. The model simulation indicates that neither a massive cut, nor a massive increase of budget lead to the best profits in the long-term. Rather a carefully implemented adjustment of the budget at a small scale of plus 10% is suggested to realize an increase of the long-term profits. The results of the long-run simulation are counterintuitive and are explained by means of systems approach archetypes like the worse-before-better scenario, information delays, level effects and limits to growth.

Keywords: System Dynamics, Modelling, Simulation, Management Decisions

INTRODUCTION

The Swiss health care system is facing complex problems due to cost reduction pressure, mergers & acquisitions and the implementation of new information systems and billing processes on basis of the mandatory introduction of Diagnosis Related Groups (DRG) by the year 2012. The hospital systems have to evaluate and deal with these “wicked” challenges or “messes” under limited financial and personal resources.

A bilateral research project between the University of St. Gallen and a major Swiss public city hospital (further referred to as the City Hospital) evaluated different methods to deal with complexity and to moderate learning on different organizational levels. It was found that complex problems can be successfully addressed by methods based on systems thinking allowing for a holistic analysis of the relevant issue (Mingers/White 2010, Schwaninger 2009, Jackson 2003 and 2000). One of these approaches is System Dynamics (SD), which will be introduced in this paper by means of applying the SD research process to a subset of research questions from the case study.

SD is described as a methodology for learning in and about complex systems. The research process follows iterative steps of theorizing, modelling, simulation and reflection, and is supported by computer software (for this project Vensim® DSS Version 5.10a was used) and a wide knowledge base in the literature (cf. for example Sterman 2000, Lane 1999, Vennix 1996).

The empirical data and the system knowledge for the project is grounded on a case study in the City Hospital and was gathered by means of group modelling for high-level concept models, interviews, workshops, documents and media watch (cf.

Table 6 in the Appendix). The SD modelling and simulation process which is discussed in this paper was conducted by the authors and the results were evaluated with two SD method experts and one domain expert from the top management of the City Hospital. The following SD research process was applied which is also reflected in the structure of this paper (cf. Table 1):

Table 1. Research Process (cf. Schwaninger/Hamann, 2005, 57).

Paper structure/Research Process	Products
1. Problem Identification	Purpose statement, Research questions
2. Dynamic Hypothesis and Reference Mode	Dynamic hypothesis, High-level system diagram, Reference behaviour pattern
Mapping the Causal Loop Structure	Causal loop diagram (CLD); with references to the stock and flow diagram sub-models (cf. Figure 11 in the Appendix)
3. Modelling the Stock and Flow Diagram	Stock and flow diagram, Computer simulation model, Report of simulation results
4. Validation and Simulation	Validation (theoretically and empirically) and Simulation results of model and policies
5. Insights and Conclusion	Policy evaluation, Policy suggestion

PROBLEM IDENTIFICATION

Resource allocation creates costs for the public City Hospital and therefore budget restrictions for the Education & Training Department (EDT) are discussed. On the one hand, the board of the corporate group, which the hospital is part of, intends to increase profits by means of decreasing the budgets for the EDT. On the other hand, the managing director of the City Hospital evaluates this perspective rather to be a short-run view. He believes that the hospital could generate more profits in the long-run, if the budget for EDT could be increased.

Research Questions

This SD research project investigates the issue by means of building and simulating a system model in order to suggest the adequate policy. Therefore, the research questions are:

RQ1: Can a model be built that allows replication and simulation of the issue at hand?

RQ2: If so, how do changes on budget allocation to EDT affect the profits of the hospital?

RQ3: And finally, which policy should be applied?

Assumptions

"Every model is a representation of a system – a group of functionally interrelated elements forming a complex whole. But for a model to be useful, it must address a specific problem and must simplify rather than attempt to mirror an entire system in detail." (Sterman, 2000, 89) The problem of this inquiry can therefore be articulated and simplified by the following assumptions (cf. Table 2):

Table 2. Model Assumptions.

Model purpose	To inquire the dynamical effects of change in investment to EDT on the profits of the hospital in order to make policy suggestions for the budget allocation decisions.
Model users	The authors (as method expert and moderator), the board of the corporate group (with a short-run view: lower profits due to higher costs) and the City Hospital managing director (with a long-run view: first lower profits and later higher profits due to system effects).
Time horizon	Short-run = 3 years, long-run = 10 years, simulation period = 30 years.
System boundaries	The City Hospital and its sub-systems as defined in the model (cf. Figure 11 in the Appendix).

DYNAMIC HYPOTHESIS AND REFERENCE MODE

The dynamic hypothesis and the reference mode represent the mode of behaviour of the issue which is inquired (cf. Figure 1). The first represents the issue as a system of variables and their connections in a high-level closed loop diagram (CLD). The latter is a set of graphs that assume the behaviour of the important variables of the model over time. Both are described in the following. For the CLD notation cf. Sterman (2000, 137-156).

Reinforcing Loop (R)

The change in Resources allocated to Education & Training is affected by the Budget Distribution Decision. If it is decided to assign more budgets, then the amount of Resources allocated to Education and Training increases, which leads to a positive effect on Service Performance. It is assumed that with the increased resources additional education and training is offered and consumed, which leads to an increase in Service Performance. With a time delay, an increase in Service Performance generates a higher customer satisfaction, which attracts additional patients and therefore leads to a higher Number of Treated Patients.

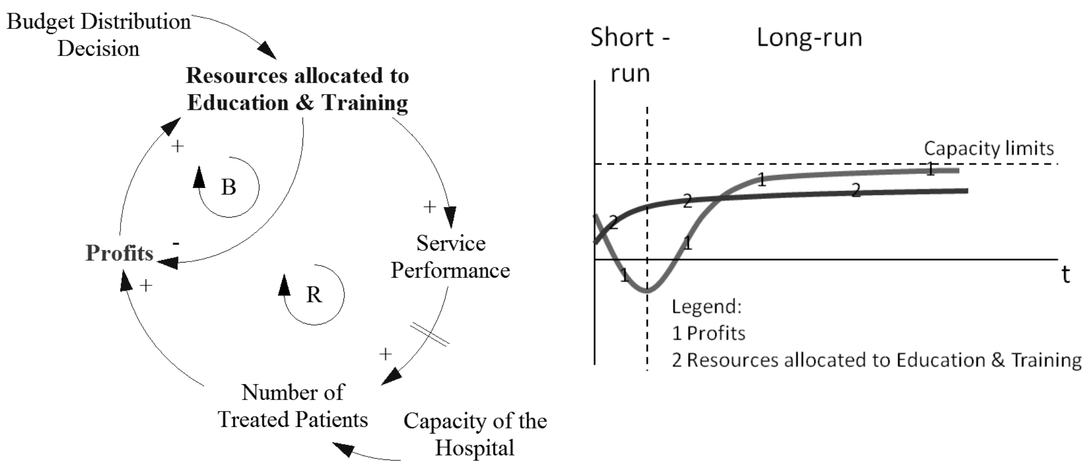

Figure 1. Dynamic Hypothesis (CLD) and Reference Mode

The delay between Service Performance and Number of Treated Patients indicates that a certain time period is needed for patients to perceive a change and to let others know about their level of satisfaction. Even if potential patients come in contact with a patient that is highly satisfied and therefore decide to prefer the hospital, it still may take some time until they actually need treatment. Further, the Number of Treated Patients which possibly can be accepted in the hospital is limited by the Capacity of the Hospital.

If the Number of Treated Patients increases, then higher Profits are realized. This again leads to an increase of Resources allocated to Education & Training in the annual budget allocation decision process, and the reinforcing loop is closed. This loop can be considered as the long-run view due to the time delay between a change in Resources allocated to Education & Training and the effect of higher Profits. Furthermore, the reinforcing loop can generate a decreasing behaviour as well. If fewer Resources are allocated to Education & Training, then ultimately fewer Profits are assumed to result.

Balancing Loop (B)

If more budget is allocated, then costs are generated which lead to fewer Profits. Therefore in the next budget distribution decision process the Resources allocated to Education & Training are cut. This reduction leads to higher Profits due to lower costs. In the next budget round the resource allocation is increased again, and so forth. This loop can be interpreted as the short-run view with a balancing effect.

Reference Mode

The short-run view is referred to the board of the corporate group and indicates a decrease of the Profits if the Resources to Education & Training are increased. That is why the board tends to shorten the budget. The City Hospital managing director shares the view of a decrease in Profits due to more budgets first, but adds the view of increasing Profits over a longer period. The assumption of these long-run effects is based on the hypothesis that more budgets would lead to more Service Competence and finally would attract more patients to the hospital. However, the realization of increased Profits is assumed to be restricted by the Capacity limits of the Hospital.

In the next chapter a more detailed model with additional explication of the links between the relevant variables is discussed.

MODELLING THE STOCK AND FLOW DIAGRAM

The relevant feedback loops of a system, concerning the issue which is inquired, can be represented as closed loops in a stock and flow diagram. “The feedback loop implies the circularity of cause and effect, where the system produces the decision which produces the action which produces change in the system. One has not properly identified the structure surrounding a decision point until the loops are closed between the consequences of the decision and the influence of those consequences on future decisions.” (Forrester, 1968, 84)

“The clear separation of system concepts into the two classes of variables - levels [stocks] and rates [flows] - has interesting and useful consequences. The level variables are the integrations of those rates of flow which cause the particular level to change. It follows that a level variable depends only on the associated rates and never depends on any other level variable.” (Forrester, 1968, 85) The stock and flow model for the concerned issue in the City Hospital consist of nine important feedback loops and the four sub-models (1) Population Growth Model, (2) Adapted Bass Model, (3) Capital and Competence Model and (4) Low Error Performance & Learning Model, which are introduced hereafter. For the stock and flow diagram notation cf. Sterman (2000, 191-230).

Population Growth Model

The Population Growth Model consists of Loop 1 (cf. Figure 3) which is a balancing feedback loop.

Loop 1: Population Growth (B)
The (L1) Population Growth loop is supposed to generate an increase of the Total Population of the Market Area from 130’000 to 140’000 persons between the year 2009 and 2019, as it is forecasted by the city authorities. The market area size of the City Hospital is restricted by the Capacity Limit of the Market Area and is estimated at 170’000 persons, which reflects a historical maximum of 166’000 persons in 1962 (cf. Stadt Bern 2010).

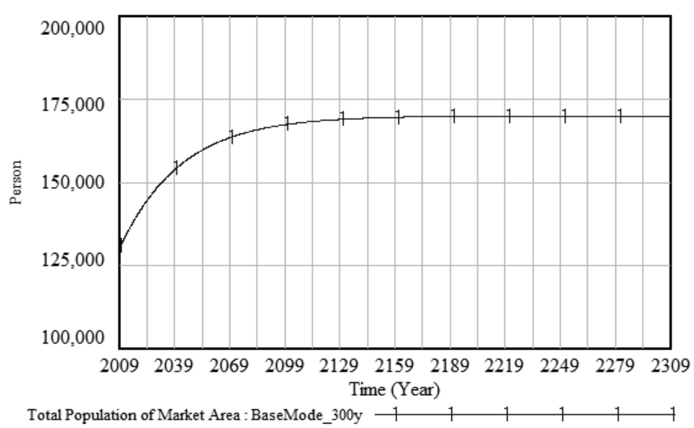

Figure 2. Population Growth Model (L1).

The population Net Growth Rate is generated from the Capacity Gap between the actual number of Total Population of Market Area and The Capacity Limit of Market Area, and by the Fractional Net Growth Rate. The result is a goal seeking behaviour (cf. Sterman, 2000, 111). Since the limit of the Capacity of the Market area is not reached in 100 years, which is beyond our time horizon for the simulation of 30 years, the goal seeking behaviour seems therefore adequate for the model purpose (cf. Figure 2).

The number of Total Population of Market Area is the sum of Potential Patients of the Market Area and Patients in Treatment in the City Hospital. Due to simplification reasons, the variable Potential Patients contains all potential patients who are not actually patients of the City Hospital, which includes patients without need for treatment, patients which need treatment but did not yet decide to enter a hospital and patients which choose to visit another hospital.

The Population Growth Model is connected to the Adapted Bass Model, which is described in the next chapter, through the variables Total Population of Market Area and Potential Patients of Market Area (cf. Figure 3).

Adapted Bass Model

The Bass model was originally introduced by Frank Bass in 1969 to explain the innovation diffusion process of new products (cf. Sterman, 2000, 332). For our purpose the model was adopted and the three loops (L2) Natural Adoption, (L3) Word of Mouth and (L4) Billing are discussed in the following (cf. Figure 3).

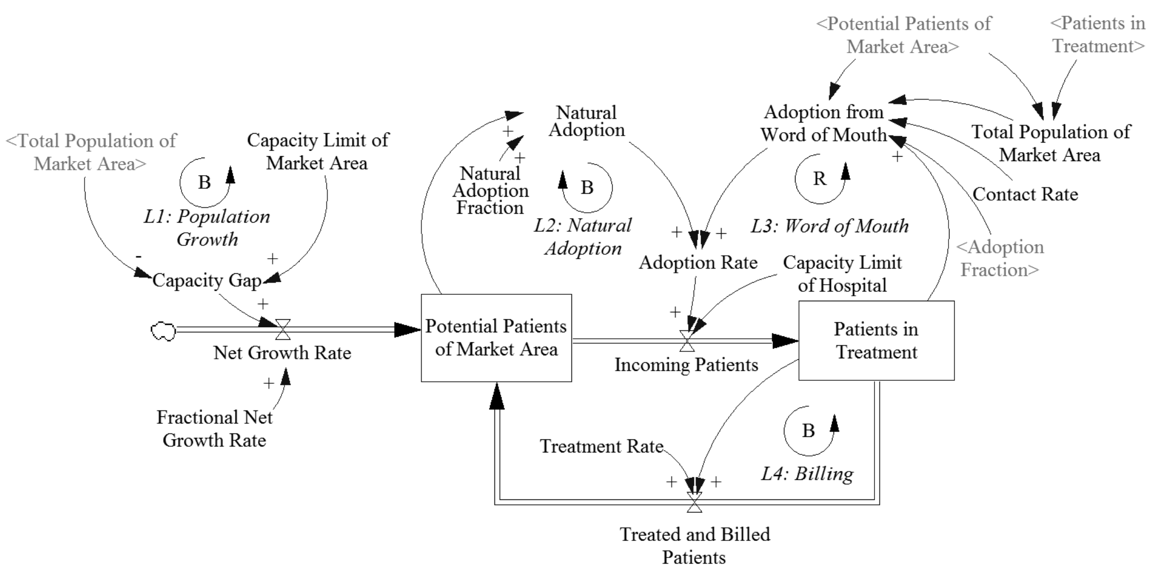

Figure 3. Growth Model (L1) and Adapted Bass Model (L2-L4) (cf. Sterman, 2000, 343).

Loop 2: Natural Adoption (B)

The variable Natural Adoption of the (L2) Natural Adoption loop includes patients who do not implement other choices than to visit the City Hospital, because they ever did so, live close, were assigned by a third party or due to other reasons. Natural Adoption is generated on the basis of the Potential Patients of Market Area and the Natural Adoption Fraction. The Adoption Rate is growing as the Total Population of the Market Area is increasing as described in the (L1) Population Growth Loop. Incoming Patients are generated due to Natural Adoption and Adoption from Word of Mouth and limited due to the Capacity Limit of the Hospital. The loop shows a balancing characteristic.

Loop 3: Word of Mouth (R)

In the (L3) Word of Mouth loop additional Incoming Patients are generated due to an additional Adoption Rate. These patients are persuaded to visit the City Hospital by contact with persons who have experienced a positive service competence and who recommend it. Adoption Fraction is a variable to measure the level of Customer Satisfaction and will be explained in more detail later. (P) Potential Patients of Market Area, (A) Patients in Treatment, and (N) Total Population of Market Area are used to calculate the Adoption from Word of Mouth according to the following formula (cf. Sterman, 2000, 333):

Adoption from Word of Mouth **=** Contact Rate c * Adoption Fraction I * Potential Adopters P * Adopters A / Total Population N

After treatment is completed Patients in Treatment leave the hospital, which results in Treated and Billed Patients according to the Treatment Rate. The patients are again part of the Potential Patients of the Market Area and the reinforcing loop is closed.

Loop 4: Billing (B)
Loop (L4) indicates the Billing process. Only patients which are treated and billed generate revenues for the hospital. It is assumed that either the patients or their insurances pay the bills immediately. This loop shows a balancing characteristic.

The Adapted Bass Model is linked to the Capital and Competence Model with the variables Treated and Billed Patients, and Adoption Fraction, which will be discussed in the following chapter.

Capital and Competence Model

The Capital and Competence Model (cf. Figure 4) was derived from the Klagenfurt Model (cf. Schwaninger 2010). The model consists of the five loops (L5) Long-run Profits, (L6) Short-run Costs, (L7) Low Error Performance & Learning, (L8) Adaptive Expectations and (L9) I Like the Hospital, which are now explained.

Loop 5: Long-run Profits (R)
Loop (L5) Long-run Profits includes the Total Revenues and Total Costs calculation, which can lead to an accumulation of Capital. Total Revenues and Total Costs are calculated as multiplication of Treated and Billed Patients with the Baserate (which equals the average revenue per patient) and the Total Costs without Costs for Education & Training, respectively. Further included in the Total Costs are the Total Costs for Education & Training.

In the long-run, higher Profits can be realized by more patients and a higher quality of service, which leads to lower Costs per Patient without Costs for Education and Training. These effects are further discussed for the loops (L7) Low Error Performance & Learning and (L8) Adaptive Expectation below. The variable Accumulated Profits is used to compare the results of the model simulation for different periods in time. The Loop (L5) Long-run Profits is balancing.

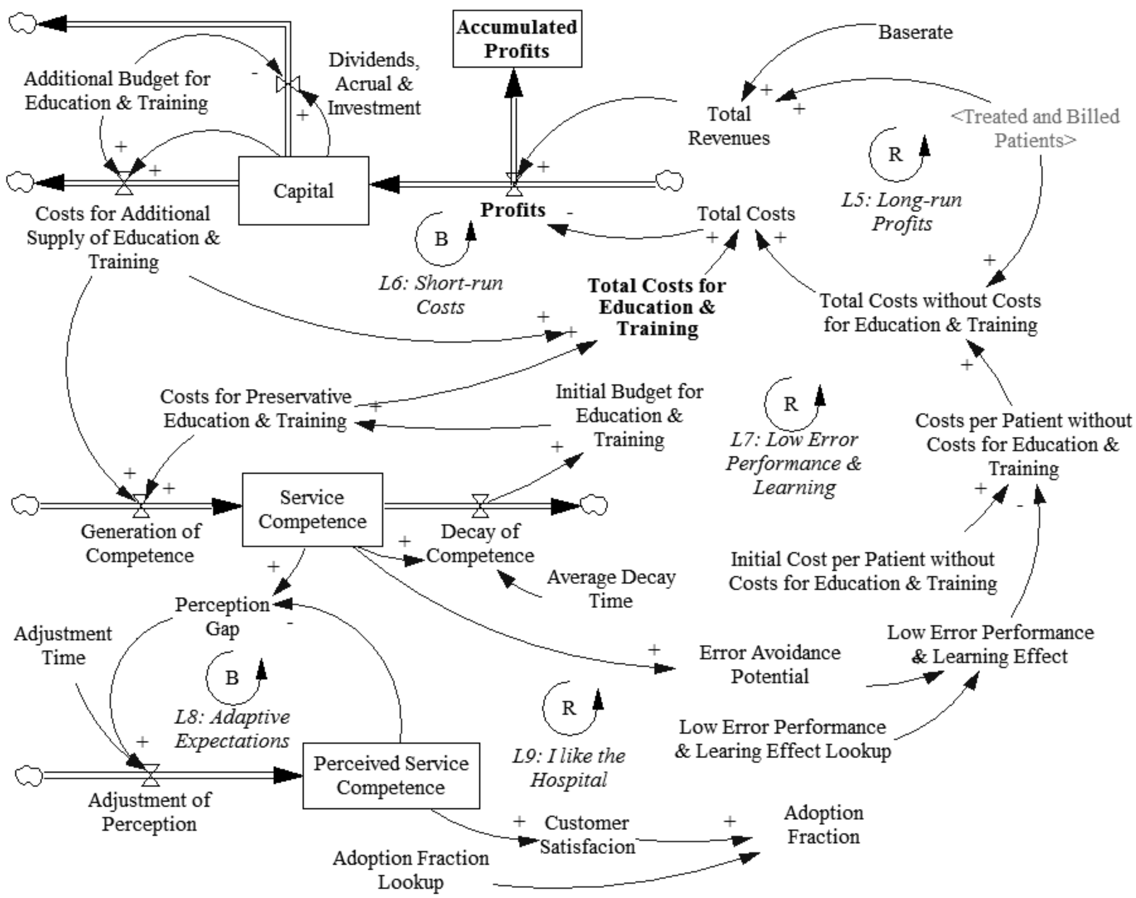

Figure 4. Capital and Competence Model (L5-L9).

Loop 6: Short-run Costs (B)
In loop (L6) Short-run Costs the cost structure is modelled. Higher Profits lead to a higher capital inflow into the Capital stock. Now, a budget distribution decision implies how the Capital is split between investment as Additional Budget for Education & Training and other Dividends, Accrual & Investment. Both generate a capital outflow.

The Costs for Additional Supply of Education & Training on the one hand lead back into the Total Costs for Education & Training and on the other hand, generate Service Competence. The Initial Budget for Education & Training, which are derived from the Decay of Competence, lead to Costs for Preservative Education & Training, which again adds to the Total Costs for Education & Training. The Decay of Competence depends on the stock level of the Service Competence and the Average Decay Time. The loop shows a balancing characteristic.

Low Error Performance & Learning Model

For the Low Error Performance & Learning Model the implication of the three Loops (L7) Low Error Performance & Learning, (L8) Adaptive Expectations and (L9) I Like the Hospital are discussed in the following.

Loop 7: Low Error Performance & Learning (R)
An increase of Service Competence due to a higher staff qualification and more team coherence in loop (L7) Low Error Performance & Learning leads to lower errors and a

learning effect. The Low Error Performance & Learning Effect is modelled with the table function (cf. Sterman, 2000, 552-562) Low Error Performance & Learning Effect Lookup (cf. Figure 5) and linked to the Error Avoidance Potential.

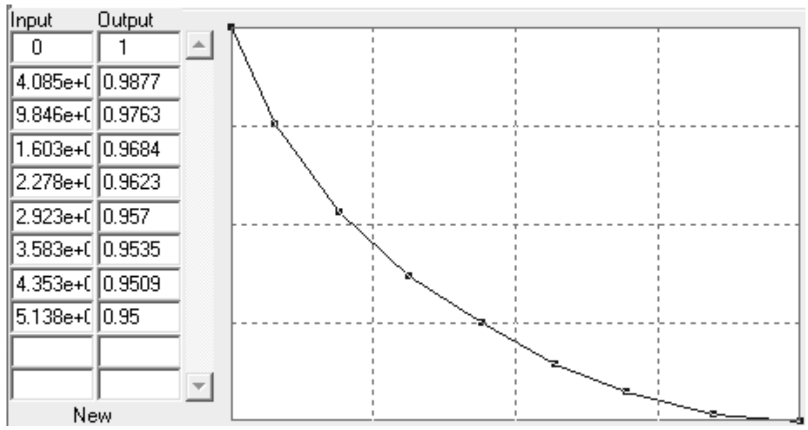

Figure 5. Low Error Performance & Learning Lookup (Table Function 1).

The table function can be read for example: If the Service Competence level is at CHF zero, then no effect can be realized and the costs stay at their initial level of 100%. If a Service Competence level of CHF 50 Mio. is achieved, then an effect of 5% can be realized and Initial Costs per Patients without Cost for Education & Training are multiplied by 0.95. The table function is an assumption, an artificial construct to reflect the ability to save up to 5% of the Initial Cost per Patient without Costs for Education & Training due to learning effects. The loop (L7) Low Error Performance & Learning is reinforcing.

Loop 8: Adaptive Expectations (B)
An increase in Service Competence results in a higher Perceived Service Competence. Between the increases of the first ant the latter, a perception delay occurs due to a certain time period until the patients have adapted their mental models to the actual conditions (cf. Sterman, 2000, 409-467).

In the loop (L8) Adaptive Expectations the delay time for Adoption from Word of Mouth is implemented as an adaptive expectations delay function (cf. Sterman, 2000, 426-432). Between the Perceived Service Competence and the actual level of the Service Competence lies a Perception Gap. This gap exists due to an information delay: “All beliefs, expectations, forecasts, and projections are based on information available to the decision maker at the time, which means information about the past. It takes time to gather information needed to form judgments, and people don’t change their minds immediately on the receipt of new information.” (Sterman, 2000, 426) Therefore, Adjustment of Perception depends on the Adjustment Time. This loop shows a balancing characteristic.

Loop 9: I Like the Hospital (R)
In loop (L9) I Like the Hospital, another table function is implemented to express the connection between the Perceived Service Competence, the Customer Satisfaction and the Adoption Fraction (cf. Figure 6). A higher level of Perceived Service Competence leads to a higher Customer Satisfaction.

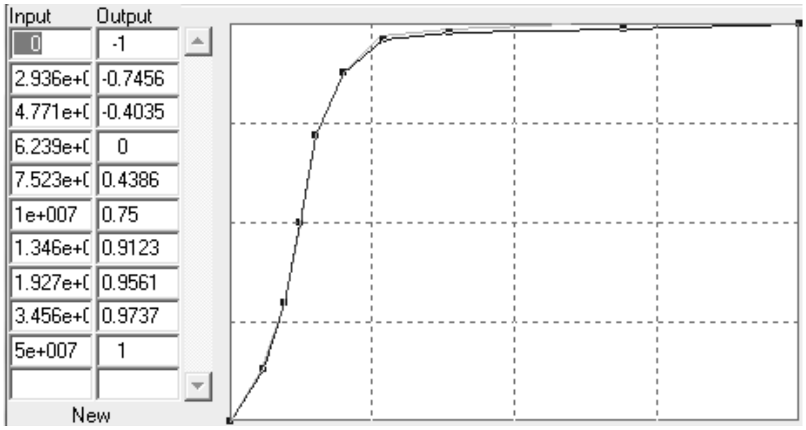

Figure 6. Adoption Fraction Lookup (Table Function 2).

The table function is an assumption, an artificial construct that intends to indicate that it takes tremendous financial and personal commitment from CHF 7 Mio. up to 50 Mio. on a high level of 75% to further raise the level of Customer Satisfaction, if that is possible at all. Contrary, if the level decreases from CHF 7 Mio. to CHF zero, the Customer Satisfaction falls rapidly from 75% to zero, which indicates that satisfaction can be lost much quicker than it can be gained or maintained, respectively.

The table function can be read for example: If the Service Competence, and therefore the Customer Satisfaction, is at a level of CHF 7 Mio., then the Adoption Fraction which generates Adoption from Word of Mouth is 0.75. If the Customer Satisfaction is at a level of CHF 50 Mio. the Adoption Fraction is 1. If the Customer Satisfaction is at zero, an Adoption Fraction of -1 is generated. This affects Adoption from Word of Mouth, because Patients in Treatment recommend to visit or not to visit the hospital to potential new patients of the Potential Patients of the Market Area (according to the Word of Mouth formula). The Adoption Fraction connects the Capital and Competence Model to the Bass Model, where the Adoption Fraction affects the Adoption from Word of Mouth.

VALIDATION AND SIMULATION

In the following the applied validation tests, as well as the simulation results for the base run and the scenario runs are discussed. Afterwards an explanation for the simulation results is given.

Applied Tests

"Validation is the process by which model validity is enhanced systematically. It consists in gradually building confidence in the usefulness of a model by applying validation tests [...]. In principle, validation pervades all phases of the modeling process, and, in addition, extends into the phases of model use and implementation." (Schwaninger/Grösser, 2009, 9000) Therefore, validation was conducted throughout the model building process on early versions and 'unfinished' parts, as well as on the final model.

Table 3 shows the tests which were conducted to establish confidence in the soundness and usefulness of the model and the simulation results. Three notable findings from the Parameter Examination Test and from the Boundary Adequacy Structure Test are discussed in the following.

Table 3. System Dynamics Model Validation Tests (cf. Schwaninger/Grösser 2009).

Applied Tests	Results/Comments
1. Issue Identification Test	Domain expert evaluation of model, simulation results and policy suggestions; the "right" problem has been identified.
2. Structure Examination Test	Vensim equation report; approved ok.
3. Parameter Examination Test	Domain expert evaluation of empirical and assumed data; approved sound and useful.
4. Extreme Condition Test	Results are plausible for each equation (direct) and for sub-models (indirect).
5. Boundary Adequacy Structure Test	Domain expert evaluation of system boundaries (cf. Figure 11 in the Appendix); approved sound and useful.
6. Dimensional Consistency Test	Vensim model check; all tests at the individual equations are passed and a large system of dimensionally consistent equations resulted.
7. Behaviour Sensitivity Test	Vensim sensitivity simulation report; plausible results.
8. Symptom Generation Test	**Testing against dynamic hypothesis (cf.** Figure 9); plausible results.

Parameter Examination Test
Model parameters were identified which correspond to the real system relatively but not in all absolute values. Profits for the base run are higher than the empirical Profits in the initial year by a factor of 10. Due to the relative consistency between the model variable, this result can be considered as a shift of level. A level correction is assumed to result in a similar behaviour pattern and can be realized by further tuning of the model. However, such an adjustment is expected to even the amplitudes of the scenario graphs which now are favoured to study and demonstrate the concerned dynamical effects due to their explicit patterns.

Boundary Adequacy Structure Test
In an early stage of the modelling process the impact of staff turnover seemed important. Therefore, the reinforcing loop Happy Team was included (cf. Figure 11 in the Appendix). During the data gathering and validation process the employee turnover was found to be very low for all departments of the hospital. During the Boundary Adequacy Structure Test the loop was excluded from the final model due to the lack of influence of a low and constant turnover rate.

While Adoption through Advertisement and Media Reports is included in the closed loop diagram (cf. Figure 11 in the Appendix), it is excluded from the stock and flow diagram. It was found, that the media reports were supporting a rather negative image of the hospital. Adoption through Advertisement and Media Reports was therefore considered to be zero and excluded from the model.

Simulation Results

For the model simulation in Vensim the time horizon is 30 years and Euler integration was used with time step (dt) set to 0.125. In the following the base mode run, the outcomes of the different scenario tests and an explanation of the results are presented.

Base Mode Run
The results for the base simulation in Figure 7 show that without Additional Budget for Education & Training, the Total Costs for Education & Training (cf. graph 3) stay constant at CHF 3.333 Mio., which equals the annual Decay of Competence. Profits (cf. graph 2) increase due to a natural growth of Total Population of the Market Area. The goal seeking behaviour leads to a decrease of increase of the Profits and is determined by the maximum conditions of the Population Growth Model. The Accumulated Profits (cf. graph 1) are used to compare the results of the scenario tests for different points in time.

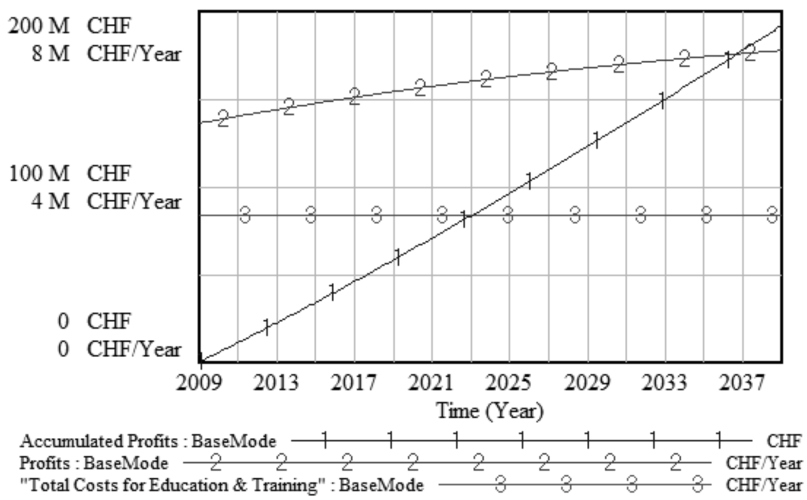

Figure 7. Base Mode Run.

For the sake of simplicity the results of this measurement variable are not discounted to net present values. The following accumulation effects can be observed: Although the increase of the annual Profits decreases, the Accumulated Profits still grow exponentially due to the fact that each year higher Profits are summed up to the accumulated total as in the year before (cf. Doerner 1996).

Scenario Tests
The time horizon from year 2009 to 2012 is defined as the short-run period, and from year 2009 to 2019 as the long-run period, respectively. The three policies Less, Same and More annual budget to Education & Training were simulated for different scenarios. The implications for the simulation parameters are displayed in the Appendix (cf. Table 5).

In Figure 8 the simulation results for the Profits of each scenario are presented and a worse-before-better pattern can be recognized. If the results from the Accumulated Profits are ranked for the short-run period at year 2012 (cf.

Table 5 in the Appendix), the Scenario (1) Less -100% with CHF 17.80 Mio. is first, (2) Less -50% with CHF 17.73 Mio. is second and (3) Less -10% with CHF 17.00 Mio. is third best. So far the simulation results are not surprising, since it seems intuitively comprehensible that Profits can be raised by means of cutting short-run costs.

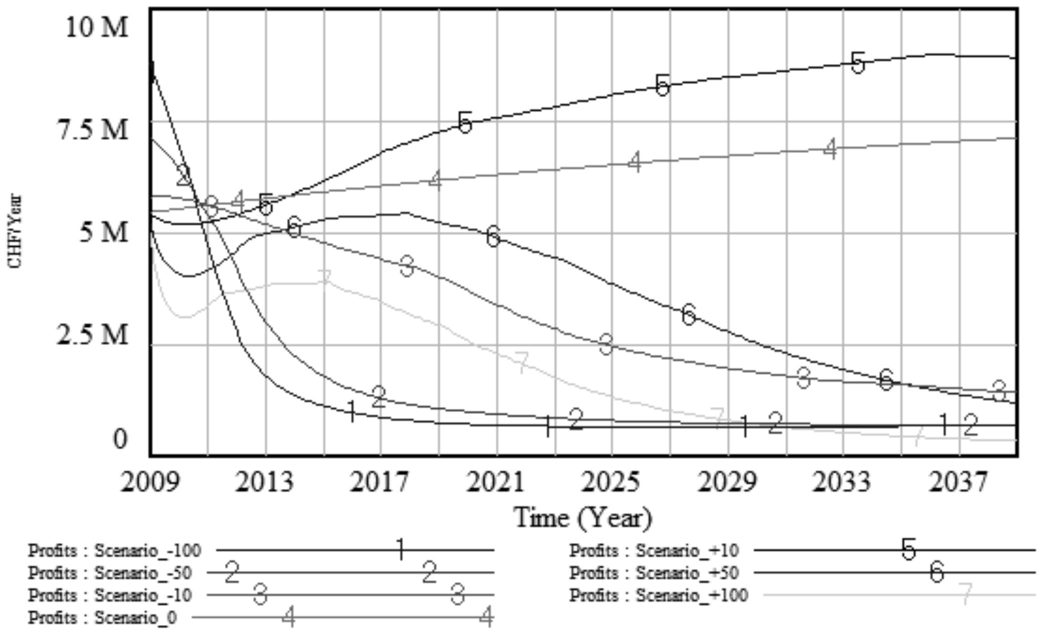

Figure 8. Annual Profits for different Scenarios.

If the long-run table for the Accumulated Profits in year 2019 (cf.

Table 5 in the Appendix) is considered, the pattern looks rather different. Scenario (5) More +10 with CHF 59.78 Mio. is first, (4) Same 0 Base Mode with CHF 58.18 is second and (3) Less -10% with CHF 49.89 Mio. is third best. We face a rather counterintuitive behaviour for the ranking might be expected to follow a continually increasing or decreasing order, respectively. However, the dynamical behaviour shows a switching pattern while the ranking of the long-run results alternates between the policies More and Less. The causes for this behaviour are discussed in the next chapter.

INSIGHTS AND CONCLUSION

This SD research project aimed at investigating the issue concerning the resource allocation decisions to the Education & Training Department in the City Hospital by means of building and testing an adequate model of the issue system. After drawing an answer from this process to each of the three research questions, limitations are pointed out and finally, an outlook for further work is made.

ad RQ1: The Model allows Replication and Simulation of the Issue

To evaluate the adequacy of the model, the Replicated Reference Mode is compared to the initial Reference Mode Hypothesis (cf.

Figure 9). The left side shows the simulation results of the Scenario More +10%, which generated the best result for the Accumulated Profits in the long-run, and on the right side the initial behaviour assumption of the issue is displayed.

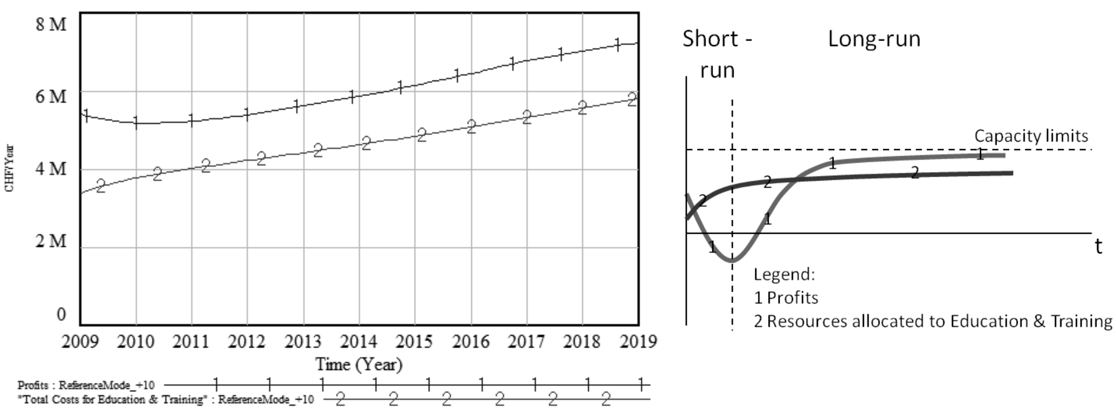

Figure 9. Reference Mode Replication vs. Reference Mode Hypothesis.

In both figures the Total Costs for Education & Training (cf. graph 2) first increase and then level off. Likewise in both figures Profits (cf. graph 1) decrease first and later increase to finally seek a limiting goal. Although the levels of the graphs differ between the simulation and the hypothesis, their behaviour pattern could be replicated adequate.

It could be shown by means of discussing the simulation results of the Profits, hat the model supports a short-run view as well as a long-run view. The board of the corporate group intends to increase Profits by cutting budget for the Education & Training Department, which leads to a better result than no change in the short-run, but to a worse result in the long-run. Therefore, the long-run estimation of the management director could be supported, that with more budgets or at least the same, higher Profits could be realized compared to a budget reduction.

ad RQ2: How Changes on Budget affect the Profits

The SD project fostered learning about dynamical effects throughout the modelling and simulation process. The following archetypes of systems thinking were encountered and will now be discussed: (1) Counterintuitive Behaviour, (2) The Worse-before-better Scenario, (3) Level Effects and (4) Limits to Growth Effects.

Counterintuitive Behaviour
The simulation results show that an increase of the Additional Budget for Education & Training of 10% leads to the best result of all simulation runs in the long-run. However, an increase of 50% or 100% generates worse results than the Base Run with no additional budget allocation. One would most probably assume that if the result for 10% more budgets is better than for no additional budget, a further increase of budget allocation would result in even better results. Due to systemic effects this assumption is wrong and contains potential for learning about policy implications and the management decision process. According to Sterman (2000, 22) dynamic complexity arises because systems are counterintuitive: "In complex systems cause and effect are distant in time and space while we tend to look for causes near the events we seek to explain. Our attention is drawn to the symptoms of difficulty rather than the underlying cause. High leverage policies are often not obvious."

Worse-before-better Scenario
In an early time period the Scenario More +10 creates fewer Profits than the Scenario Same due to higher Costs for Additional Supply of Education & Training (cf. Figure 8). However, this additional supply leads to an increase in Service Competence in the long-rung, and ultimately, to a higher Adoption from Word of Mouth as a result of an increased Customer Satisfaction. Due to the Adaptive Expectations Delay of the patients, a certain time period passes until the Scenario More +10 outperforms the Scenario Same. The pattern of lower Profits first and an increase later, generates a worse-before-better scenario which can best be expressed in the metaphor that a seed needs to be sowed before harvesting is possible.

Level Effects
The graphs in Figure 8 display the consequences of operating at a high Customer Satisfaction level. Since the initial value is assumed at a level of 75%, it is easier to lose Customer Satisfaction by neglecting Service Competence than it is to further increase it. These circumstances are incorporated in the model by the table function in Figure 6. The sensitivity of the Profits on the change in Additional Budget for Education & Training is reflected in the different scenario outcomes: As the hospital operates at a high level of Customer Satisfaction, Profits are highly sensitive on the reduction of budget. In the Scenarios with restricted budgets, the Decay of Competence is not adequately accounted for, and with a delay, the Customer Satisfaction decreases and so does the Adoption from Word of Mouth. Since fewer patients are attracted to the hospital, less Treated and Billed Patients generate Revenues, which ultimately results in a decrease of the Profits.

Limits to Growth Effects
In Figure 10 the results for Profits and Total Costs for Education and Training are illustrated for Scenario More +10. While the first tend to level off towards a limiting condition, the latter still are increasing due to an annual increase of budget. The examination of the simulation results show, that the Capacity Limit of the Hospital is not exhausted within 35 years, but limits to growth seem to be reached within 20 years, when the Total Costs for Education & Training exceed the Profits. A closer look showed that for the long-run period of 10 years, that the limiting condition for growth is determined by the ability of the hospital to attract further patients in addition to the Natural Adoption and Adoption from Word of Mouth (cf. Figure 3). In other words: The limits to growth

are not determined by the Capacity Limit of the Hospital, as one might expect first, but by the ability to attract additional patients to operate the hospital at the full capacity.

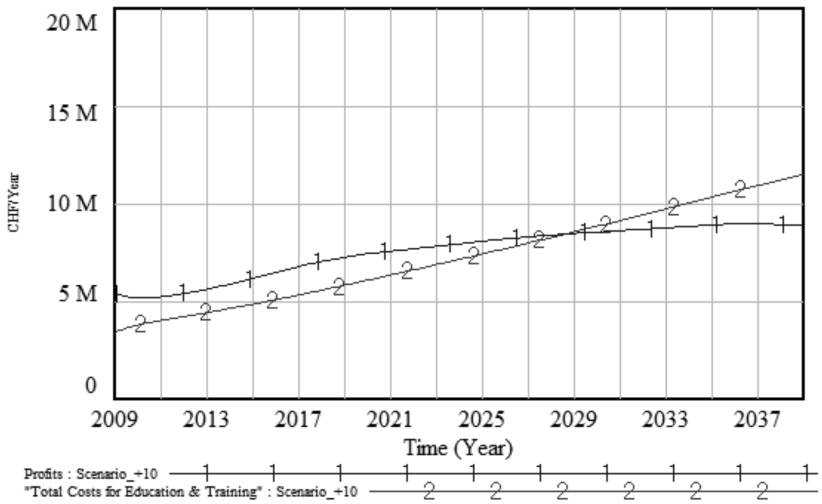

Figure 10. Limits to Growth of Reference Mode.

In the initial model the impact of advertisement on customer adoption was presumed to be zero or slightly negative. Therefore, it is suggested to attract additional patients by means of implementing an advertisement strategy and by other interventions. A relevant positive impact is expected from an advertisement campaign for such is actual non-existent. However, for these interventions capacity limits and their time span must be taken into account.

ad RQ3: Policy Suggestion

Based on the simulation results and the discussed findings it is assumed that cutting the budget will most probably lead to a decrease in Profits and that the status quo or a slight increase in budget allocation for Education & Training would lead to better results. However, due to level effects and the high sensitivity of Profits on budget changes, this increase should be implemented very carefully and only on a small scale, in addition to further interventions. The following policy is suggested:

Keep the budget for the Education & Training Department unchanged or slightly increase it by about 10%. Further, try to attract additional patients as long as the capacity limits of the hospital are not exhausted.

LIMITATIONS AND OUTLOOK

The modelling and simulation process was largely conducted by the authors, informed by data and knowledge gathered in a case study about the City Hospital. Although the empirical data and the assumptions, the final model and the simulation results were evaluated with two SD experts and a domain expert of the top management level at the hospital, the validity further depends on the theoretical, conceptual and dimensional testing. Additional involvement of domain experts and concerned persons in the modelling process and for feedback on the model and the simulation results is desirable for further improvement.

All parameter values and variables which were assumed and not gained from empirical evidence are to be considered as limiting for the validity and usefulness of the model. For further research, these assumptions should be investigated in more detail and the model should be upgraded accordingly. For example an additional feedback loop for the suggested adoption from advertisement can be implemented in the Bass model for further simulation and policy evaluation.

The mentioned limitations could be overcome, or at least weakened, if the issue would be investigated by means of a group modelling process (cf. Vennix 1996). If further domain experts from the board of the corporate group and the hospital would join the research project, then probably an even more accurate and useful model could result. Thereby a good chance for enhancing mental models (cf. Senge 1990), enabling mutual learning and fostering systems thinking would be offered, which is “a double-loop learning process in which we replace a reductionist, narrow, short-run, static view of the world with a holistic, broad, long-term, dynamic view and then redesign our policies and institutions accordingly.” (Sterman, 2000, 18)

APPENDIX

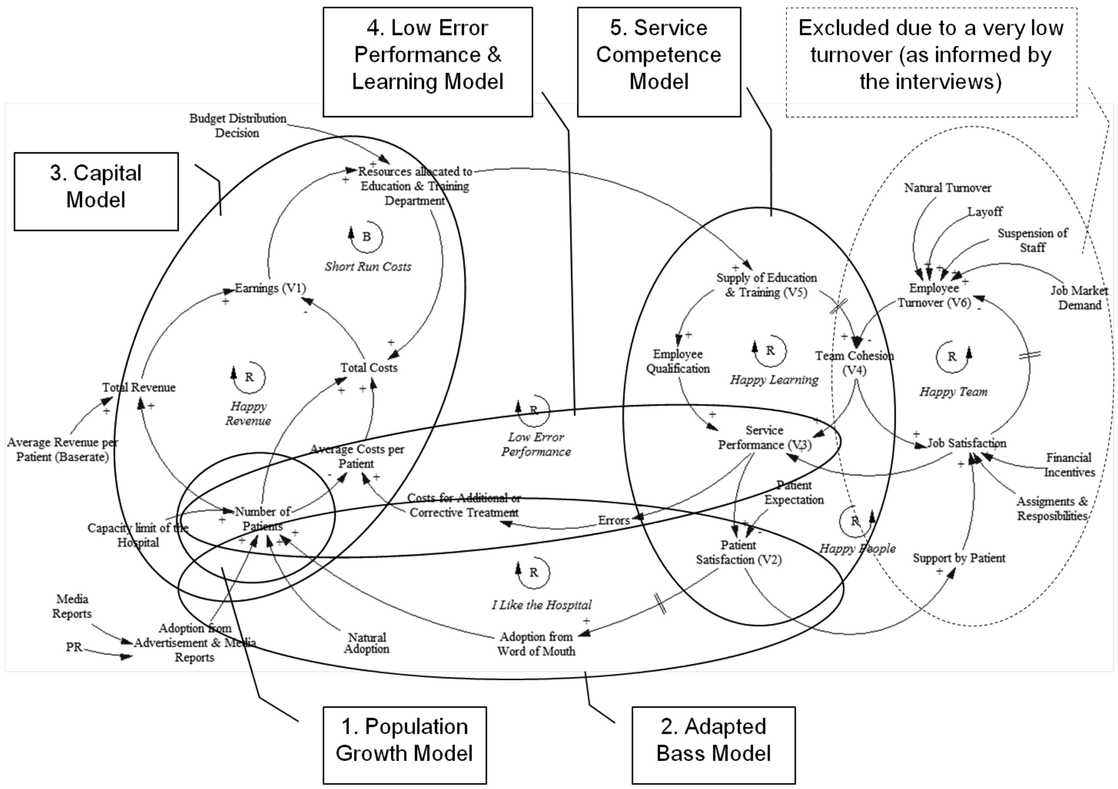

Figure 11. Closed Loop Diagram (CLD) with links to Stock and Flow Models.

Table 4. Implication of Policies and Scenarios for Model Parameters.

Policy	Scenario	Variable	Value
Less	{-100, -50, -10}	"Additional Budget for Education & Training" =	0
		"Initial Budget for Education & Training" =	Decay of Competence {*0, *0.5, *0.9}
Same	0	"Additional Budget for Education & Training" =	0
		"Initial Budget for Education & Training" =	Decay of Competence
More	{+10, +50, +100}	"Additional Budget for Education & Training" =	{*0.1, *0.5, *1}
		"Initial Budget for Education & Training" =	Decay of Competence

Table 5. Ranking of the Simulation Results for Different Scenarios.

Policy	Scenario	Label in Figure 8	Accumulated Profits			
			Short-run (year 2012)		Long-run (year 2019)	
			Mio. CHF	Rank	Mio. CHF	Rank
Less	-100%	1	17.80	1st	26.43	7th
	-50%	2	17.73	2nd	31.36	6th
	-10%	3	17.00	3rd	49.89	3rd
Same	0 Base Mode	4	16.68	4th	58.18	2nd
More	+10%	5	15.75	5th	59.78	1st
	+50%	6	12.90	6th	49.32	4th
	+100%	7	10.49	7th	35.65	5th

Table 6: Glossary of Selected Model Variables.

*)	Variable	Units	Value	Comments
A	Adjustment Time	Year	0.5	
E	Average Decay Time	Year	3	Confirmed assumption by City Hospital manager.
E	Baserate	CHF/Person	7025	Total earnings/Number of patients (cf. City Hospital 2009)
E	Capacity Limit of Hospital	Person/Year	60000	Confirmed by City Hospital manager.
E	Capacity Limit of Market Area	Person	170000	Historical capacity limit 1962: 166000 (cf. Stadt Bern 2010)
E	Capital	CHF	500000	Empirical initial value (cf. City Hospital 2009)
A	Capital Outflow	CHF/Year		Max function: If Capital is negative, then no Flow is triggered = 0
A	Contact Rate	1/Year	1	Due to the small size of the Market Area
A	Dividends, Accrual & Investment	CHF/Year		Max function: If Capital is negative, then no Flow is triggered = 0
E	Fractional Net Growth Rate	1/Year	0.03	Calculated to genrate 140000 Persons in 10 Years
E	Incoming Patients	Person/Year		MIN function: Due to capacity restriction of the hospital
E	Initial Cost per Patient without Costs for Education & Training	CHF/Person	6987.5	Calculated for Base Run: 7025-37.5 = 6987.5
E	Natural Adoption Fraction	1/Year	0.25	Calculated to generate initial Adoption Fraction
E	Patients in Treatment	Person	43000	Stationary and Acute patients for initial year
A	Potential Patients of Market Area	Person	87000	For initial year
E	Treatment Rate	1/Year	1	40000 patients per year for initial year

*) A = Assumption, E = Empiric data

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