SIMULATION STUDY OF A PRIVATE DIAGNOSTIC CENTER

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Abstract

Decision making and management of health care in Greece is based mainly on financial assessment. The partial privatization of Greek health care led to increased competition and health providers are now searching for methods to facilitate decision making on qualitative and cost-related issues at an operational level.
This study is filling the gap in discrete event simulation of diagnostic health centers, and aims at outlining and disseminating the impact of simulation in the managerial decision taking process in health care management. A privately owned diagnostic center is modeled and the results are disseminated to the stakeholder company, a leader in private health care in Greece.
The center was in the process of relocating to a new location and three issues were addressed according to management inquiries: (i) current status assessment, (ii) modeling of the new center and performance assessment, and (iii) performance test in situations of increased service demand.
The project was implemented according to a precise action plan and stepwise methodology. Three scenarios were modeled and tested yielding the following main results: (i) the original format was efficient in serving current demand; (ii) the new setting improves performance and will be capable of handling increased demand; (iii) administrative staff cannot be reduced without serious performance deterioration. These findings were communicated to the center's management, they were accepted and some suggestions are implemented in the new setting by the diagnostic center management.

Keywords: Discrete Event Simulation, Health care management, Diagnostic center simulation.

Presenting Author's biography

Efthymios Altsitsiadis. Mr Altsitsiadis is a graduate of economics from the University of Macedonia, and post-graduate of two master degrees (Marketing in Katholieke Universiteit Leuven and IT and Management in Aristotle University of Thessaloniki, AUTH). He is currently enrolled in the second year of his PhD in the AUTH Medicine faculty studying health care management. He has served as a business analyst in a leading private Greek health organization, and is currently involved as a project manager in European funded health projects. He is also employed by AUTH as a lecturer of Health Care Management, and collaborates as an outsourcing consultant with a private consultancy firm.

1 Introduction

Competition in private health care services has been escalating for the past decade and has moved on to issues that reach beyond cost and price. Health providers are strategically turning their attention to qualitative aspects of their product mix as a mean to compete for new customers while maintaining their market shares. The major issue in managing qualitative elements in operational level is the complexity of even a simple system (as in this study a diagnostic center). Health centers could prove to be too sophisticated for managers to assess, and over-simplistic decision efforts based simply on cost figures and rule of thumb estimations, can lead to quality deteriorating results.

The subject of this study is a diagnostic center, member of a leading private Greek health group that was in the process of relocating to a more strategic location. The diagnostic center has been operating successfully for many years, and enjoyed a fine reputation and stable growth. Under this opportunity, management decided to launch a simulation project to assess the old status, and project this model to the future structure of the center, just before final arrangements were to take place at the new facility. The major structural difference in location is the merging of the two-floor old center to a one-floor new one.

2 Study framework

2.1 Academic scope and literature review

A thorough review of health care simulation literature indicates that Discrete Event Simulation has been widely applied in the health care sector, as the fit of problem solving capabilities of this tool and the specific nature of health care issues deems to be almost ideal. A basic analysis of the relevant bibliography suggests a rising trend of publications on the subject. This sign of increased adoption of simulation methods in medical settings could be linked with the technological evolution of simulation software on the one hand, and on the increasing importance and complexity of health care management on the other. The success stories of simulation application in health care also provide a build-up effect on support of this tendency.

There are several views on categorization of health care simulation (J. S. Carson [1979], J.C. Lowery [1996], J. Preater [2001] e.t.c.) providing a compendium of related literature. A number of review articles include recommendations, and instructions for potential modelers of health care systems. The majority of related studies however, focuses on the modeling of interactive physical systems and aims at resource planning or / and patient flow and routing. Notably, a significant variety and sub-categorization exists within this basic classification (i.e. bed sizing, human resources planning, and so on). The research subjects are also diverse, although, as expected, more research is coiled up to the level of clinics. There are however broader application cases (i.e. an entire health system) and narrowed-down cases (i.e. a single medical machine). At clinical level the most usual cases (especially in patient scheduling and admissions) are applied to outpatient clinics. Emergency rooms are the most common case in resource allocation studies.

A research gap is spotted in health care simulation studies on diagnostic centers, a common health care center format in Greece that meets the qualifications of a discrete event simulation 'customer'. Literature on discrete-event simulation of such centers is very scarce although there is evidence of practical application that did not include publication. The diagnostic center is an autonomous health unit that can provide a wide range of diagnostic services (blood analysis, CT or MRI). The major difference with a clinic is that these centers do not provide immediate treatment and are normally limited to deliver test results and to a lesser extent medical examination and consultation.

It is also a fact that simulation is rarely (or never) used as a tool in the decision taking process in private health care management in Greece, regardless of management level and impact potential. Common practice suggests that performance is predominantly assessed through financial performance.

This study tries to enrich the literature in diagnostic center simulation, but more significantly aims to point out the tool's strategic importance and potential in health management and increase its uptake by Greek health managers.

2.2 Managerial scope

The company's management was interested in a methodology or a tool to assist its decision making at operational level. Management reports, resource lists, and financial results are not adequate to facilitate precise and effective decision taking on higher levels of management, yet these are the only instruments used. Static data analysis can lead to an over-simplistic assessment of a center's performance (especially with regards to human resources), and could lead to unsafe decision making. Traditional information systems cannot provide secure information or even simple indications of quality of service. These two problems render the assessment of a center's overall performance almost impossible to be conducted by a supervisory unit (i.e. corporate analysis or decision-making related units) outside the center. On-site audits do not provide any kind of safe estimation either as the sample bias could be intolerable.

As a result, the assessment of the performance of health centers is limited to financial assessment.

Financial performance on the other hand is directly linked with operational performance. In other words, a manager cannot (or should not) try to assess a health center overall performance based only on financial data that are not well understood.

In this specific study, the diagnostic center's management is interested in addressing three issues with this study:

(i) Current status assessment (in terms of resource utilization, quality of service).

(ii) Modeling of the new center and performance assessment.

(iii) Performance test in situations of increased service demand.

It was within the methodology process of the study that new management inquiries were surfacing and addressed, such as experimentation with what-if scenarios in the model of the new center and comparative assessments of performance.

3 Methodology

The methodology implemented in this study was a mixture of commonly accepted Discrete Event Simulation methodology (References [3] and [19]) and basic project management planning methodology. An action plan was designed to break down work, to assign the work among the study team and to time-schedule the project.

The simulation methodology consisted of the following steps:

- Problem formulation and study plan

- Requirements specification

- Data collection

- Model definition

- Draft basic model and pilot run

- Basic model modifications and validation

- Design of the new center model, validation and acceptance

- Experimentation (What-if scenarios)

- Results (Performance assessment / comparative analysis)

- Suggestions/conclusions, management report

The simulation software used for modeling and analysis was Simul8 V.10. The use of Simul8 is not based on programming or statistical data, but on drawing the design of flows on screen, and only filling in numerical information where needed. Simul8 was selected because of the fit of its characteristics with the study team's needs. More specifically, the team was looking for simulation software that could deliver most of the following:

- To provide for a quick efficient design and development of a preliminary model to enhance the understanding of the structure of the simulation case.
- To be able to provide an easy-to-manipulate visual framework of the model to facilitate interaction with the center's management.
- To be able to build in numerical information when available but still have a basic functionality when information is absent.
- To include easy to use practical solutions to certain case needs (i.e. simplified resource scheduling, dynamic combination of distributions, labeling and routing of system entries,)
- To be able to provide easily understood, but rigorous, performance results that can be easily exported to other software packages.

Finally, Microsoft project was used for the projects' internal time scheduling and monitoring.

4 Implementation

The formulation of the research problem and the requirement specification was derived after three meetings of the study group with the operational director of the center, where basic requirements and potential extensions were set. The basic model was shown to the center's management two months later and it was revised twice after some critical flow problems were discovered during the face validity. The final version of the basic model was the center of all experimentation and alternative modeling.

Data collection was mainly fed by the ERP system installed in the center, which provided customer specific arrival information. The main information sheet included registration of customers in hourly spacing per group of service. Such preliminary data can be seen in the caption below: the graph represents the number of blood-samples (visits) taken per every working hour of the center over a three months period.

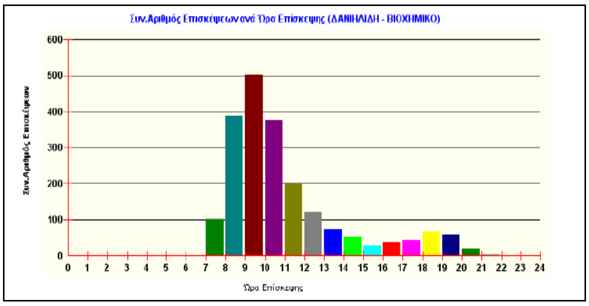

Fig. 1 A sample of basic customer information

The operational director mainly provided the remaining information. Such data are referring to average time of some health services or machine specs. For the strictly medical issues, the center's doctors provided with such estimations as basic examinations and prescription writing times. Two important limitations were detected during the study: There were no data available in concern of patients performing a combination of service groups, and there were no recorded numerical data on phone center incoming calls and their duration. A detailed list of limitations and hypotheses was included to describe the model's known inconsistencies with the real life system. The list was designed to contain and assess all known data problems along with the hypotheses made to address them. The assessment was a remark about the potential impact of each hypothesis, and was primarily derived from repetitive elasticity tests.

5 Modeling

The overall strategy in dealing with the modeling requirements emphasized the need for a model of the old center format to serve as basis for the design of the new center model and experimentation.

The old center was a two-floor structure that interconnected with an internal ladder. Each floor had its own secretariat and was operating its own distinct functions. The draft model was therefore split into three interoperable parts: Floor one, Floor two and the calling center handled by both secretariats. For each part, an activity cycle diagram was designed and then each component was transposed to a simulation object customized according to real life data.

The center deals with a significant number of customers seeking diverse health services and combos. The available data included information about different kind of customers and their respective arrival time. For each kind of customer (work item) a distinct entry point was designed to model arrival patterns. With the use of relative frequency histograms the respective probability density function for each work item group was derived to allow the design of custom probability distributions. For the basic model ten different work item groups were identified following ten different distributions. All entry points were customized with label and a named distribution that most of the time was a combination of common distributions. Labels were used in routing, prioritization and process time calculation in work centers. Resources were divided in two categories: machinery and human. Machinery resources were simulated as work centers and human resources were simulated based on the actual work shifts and duty lists.

5.1 Floor 1

The basic customer use-case scenario of the first floor is the following: a customer arrives at the center without scheduling a fix appointment. He waits in the secretariat for his registration. After registration the customer remains in the reception room till the nurse leads him to the test room. The blood sampling procedure begins shortly after. When the procedure is finished the client departs. The samples are taken to a special lab for testing (outsourced procedure that cannot be altered). The customer returns to receive the results of the tests.

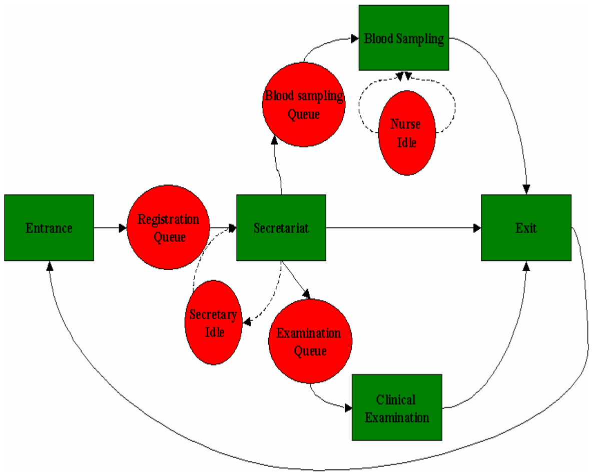

Fig. 2 Activity cycle diagram of the first floor

The floor’s major flows and structures can be seen in figure 2. This activity cycle diagram was the basis of the actual modeling of the floor. The diagram includes one entrance (as the physical center). There is no data recorded however able to trace the customers returning to the center to receive their results of the test they took earlier. There is also no fix time that this comeback is happening, i.e. one can take his results in the same day, while another can come back after a week.

A separate entrance was therefore included in the final model that was custom attributed based on some facts and hypotheses (i.e. the minimum waiting time is half day, the number of the patients returning is on average the same as the number of the patients taking tests and the results receipt is a less time consuming action then the registration).

5.2 Floor Two

The second floor is more complex than the first one, as more resources, services and flows are deployed.

Figure 3 presents the major flows and structure of the second floor. The basic workflow scenario occurs as following:

A customer enters and waits for registration at the secretariat. After registration he remains at the reception until a handler or a doctor, summon him (depending on the demanded test). The patient uses the respective machine or receives the respective medical examination and returns to the reception. A doctor dictates to a secretary the pronouncement of the results of the tests and the customer receives the tests and exits the center.

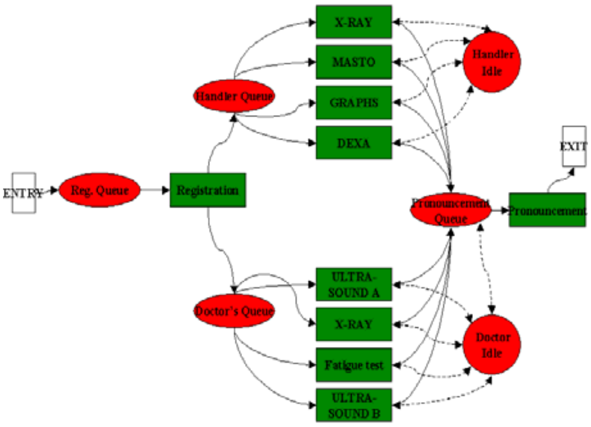

Fig. 3 Activity cycle diagram of the second floor

The floor's human resources (especially doctors) follow a complex shift schedule that became easy to implement through the simulation package's shift patterns dial-boxes.

5.3 The call-center

The center's main instrument for scheduling and servicing potential customers is the phone; therefore phone-answering quality can be considered significant. On the other hand, incoming calls account for a significant part of the secretariat workload and therefore a considerable factor to study when assessing secretariat performance. Only empirical evidence however can back up this claim, as the call center did not offer any digitized record of the phone call traffic. The center had four operating lines and both secretariats were responsible with handling all incoming calls. There were some informal guidelines on prioritization and on phone-load management and they were included in the model.

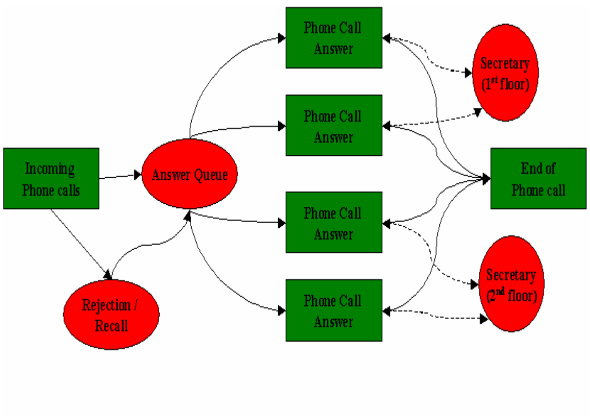

Fig. 4: Activity cycle diagram of the Call-center

5.4 The new Center format

The modeling of the new center was based solely on the validated old center model with modifications evolving mostly around the merging of the two floors and secretariats in one. All incoming patients and phone-calls are now directed to one main work-point. The model was arranged so that all entry-points are led to this one secretariat, and all secretariat out-flows are connected to all the centers functions.

5.5 Verification and validation

Model verification and validation was mainly conducted through the use of face validity checks with the operating director's contribution. The basic model was presented twice to the operating manager for face validation and corrections. The visual representation of the system and the animation of the work-flows proved efficient determinants of the success of the validation procedure. A critical error was identified in the pronouncement procedures (several unprocessed work items were pending when the late-evening doctor shift was over) that had a major impact in the system performance. A basic structural change with regards to the pronouncement process was also a result of the face validity. The pronouncement process was divided to two segments, the secretarial work (doctor's presence was not required as the results writing included a routine part) and the doctor's work (the actual medical part of the prescription).

Sensitivity analysis was conducted to study the effect of the most strategic variables under assumption. The most significant variable apt to error was considered to be the number and frequency of occurrence of the incoming calls. Since no data was available to confirm the number of incoming calls, the manager along with the secretariat provided with rule-of-thumb estimations on phone call activity regarding their average days.

Two tests were set-up to evaluate and assess the impact of the incoming phone calls on some key performance measures. The distribution of incoming calls (a combination of two distributions signifying a high and low occurrence of phone calls) was manipulated with a higher than the standard throughput of phone calls for the first test, and a lower than usual for the second. A simple comparative analysis indicated that the variation of the key performance measures was tolerable. This test suggested that one of the most significant hypotheses was 'safe' to use within the reasonable self-reporting of the staff.

Table 1 Sensitivity analysis results

Simulation Object	Performance Measure	Standard Result	Test 1 Result	Test 2 Result
Exit 2nd Floor	Minimum Time in System	16.87	16.71	14.91
	Average Time in System	**34.01**	**34.95**	**33.59**
	Number Completed	9682	9681	9682
Exit 1st Floor	Minimum Time in System	3.24	3.24	3.24
	Maximum Time in System	31.47	28.41	23.53
	Average time in system	**9.13**	**9.53**	**9.01**
	St Dev of	3.58	3.91	3.46
	Number Completed	10886	10886	10886
Answered Phone calls	**Number Completed**	**12332**	**18601**	**9178**
Secretary 1st Floor	Utilization %	47.00	54.90	43.00
Secretary 2nd Floor	Utilization %	71.80	76.20	69.70

With the use of the table and 'Time in simulation' graphs it was noted that the 1st floor's results were more sensible to incoming phone call alterations. For example the secretary utilization rose 7,9% in the first test for floor 1 against only a 4,4% in the second floor. This was a result of the internal guidelines for call answering that dictated that the first available secretary should manage the ringing phone. And since the overall workload of floor 1 is smaller, the 1st floor secretariat absorbed the increase of phone calls during test 1.

6 Experimentation and assessment

6.1 The old center

The basic model of the old center was assessed in a number of variables measuring performance of critical work points, entry points, queues and resources. Each trial was conducted for a 81-working-days time span (exactly as long as the period the real-life data that was collected) following a one-week warm up period. The period of the simulation time made it easy for direct comparisons with the real life center (i.e. throughput). The results of the basic model were categorized to three groups. Below is the structure of the results and its metrics:

1. Entry points and Queues
   a. *Entry points for both floors and for all types of customers and incoming phone calls: Measured in 'Number of entries'*
   b. *All major Queues: Measured in mean time of waiting in queue and in some cases in mean size of queue.*
2. Human Resources

   -Measured in utilization percentage
3. Main Work Centers

   -Measured in 'working' percentages

Finally the mean time in system for each floor was calculated at the two exits.

The average trial (a=95%) for each point was included in a table that was used as the basis for comparative analysis to the three follow-up scenarios of experimentation. These scenarios were developed to tackle the needs of the center's management (as described earlier).

6.2 Scenario 1: The new center

The old diagnostic center was to be abandoned to a new location that was already selected. The most important change was that the new location involved a one-floor format and apart from that modeling was based on the previous center format. The major difference is assessment was that the time in system metric was of no direct comparison use with the basic model results, as the latter included one result for each floor. In total 18 adjustments were performed to the original setting. This scenario tested the new center under the demand settings of the old center.

6.3 Scenario 2: Increased demand in the new setting

Relocation was decided upon the belief that the center will be able to draw more clients since its location would be better positioned in the market of the city. Thus the 'what if' question formulated covered this exact scenario: 'Will the new center be able to handle increased demand?'

In absence of a concrete marketing plan and the new center's marketing targets it was decided to experiment with a balanced increase that would be expected several months after the relocation. The three bigger sections were given a uniform demand boost of 10%:

Table 2 Demand modifications

Entries	Before	After	%
Ultra-sound	3.935	4.346	10
Biochemical	5.218	5.715	10
X-rays	1.684	1.854	10

The results were put in a similar table to that of scenario 1 and they were directly comparable to scenario 1 results.

6.4 Scenario 3: Reduced administrative workers

This scenario was inspired by the results of the earlier scenarios. The main problem under question is whether a cut in clerical workers would lead or not to a big change in performance. This scenario is based on the scenario 2 setting, meaning the new center layout, with increased demand, and one less secretary.

7 Results

7.1 The old center assessment

The assessment of the old center status showed that the center was able to tackle all incoming demand easily with subtle waiting times in all queues, except the prescription pronouncement queue. The medical part of the prescription pronouncement procedure had a 4.41 minutes average waiting time, which was caused by the heavy utilization of the doctors (60%). It is however considered positive that the most expensive human resource is highly utilized. The next congestion point was the queue for the X-Rays with 3.34 minutes of average waiting time, which is however considered easily tolerable in medical practice.

The results of the old center indicated an imbalance in the work load of the two secretariats. On average the secretariat of the first floor is busy 44% of its working time while the second floor secretariat is working a high 72%. It should be noted that both secretariats are equally manned and that this difference of utilization is mostly caused by the involvement of the 2nd floor secretariat in the pronouncement procedure.

The fairly low resource utilization percentages were mentioned in one of the secretariats indicating a possible reduction in staffing. Finally the low utilization of the nurses (20%) in floor 1 was reported to the center's management.

7.2 The new center results (scenario 1)

The assessment of the first scenario showed evidence of increased clerical work efficiency with queue times significantly reduced in the secretariat, indicating a better flow of work in the new setting.

Table 3 Secretariats average waiting times

TIME (in minutes)	Secretary 1st floor	Secretary 2nd floor	New Center Secretariat
Average waiting time	0,51	1,10	**0,27**
Average waiting time (excl. zero times)	1,61	2,05	**1,13**

More specifically the performance of the new center's secretariat has shown a great improvement when compared to either old center's secretariats as can be seen in table 3.

The utilization of the secretary human resource averaged a 58% which was the result of the merging of the two secretariats and the correction of the imbalance noted above. A variation of utilization (ranging from 23% to 33% utilization) of the 4 different secretary positions of the new secretariat suggested a possible testing of a new scenario with specialized (rather than generic) role for each position, as to correct this new imbalance. One potential scenario involved three specialized secretary positions and a generic (assistance) one.

7.3 The increased demand scenario results

As mentioned in chapter 6.3, in response to the center's relocation and the anticipated increase of customers, the new center model was tested with a 10% increased demand in three major sections (all other variables stable). The results indicated no significant worsening of any critical performance variable, thus indicating that the new center will easily respond to higher levels of demand without sacrificing service quality.

Table 4 Secretariat average waiting times

TIME (in minutes)	Scenario 1	Scenario 2
Average waiting time	**0,27**	**0,34**
Average waiting time (excl. zero times)	**1,13**	**1,23**

Indicative of the small impact of the increased demand are the results presented in table 4. It is noteworthy that the waiting times were not significantly affected by the supplementary work, indicating that the center is far below its maximum production capacity. The same finding is reflected on the rest of the center's results (main queues, work centers and resources).

Finally 'time in system' showed an insignificant increase (from 23:25 to 23:38 minutes in system) among the two scenarios. This metric however, should be examined deeper, as it is extremely sensitive to demand composition. In other words the reported increase would be more significant if the increase in demand is not uniformly applied over three types of service, but rather isolated to a more time-consuming service.

7.4 Scenario 3 results

In relation to the above findings, management was realizing that a reduction in the secretariat staff would be feasible and would not bear any significant impact on the improved new center's performance. The results of this experimentation showed exactly the opposite. The reduction of one secretary resulted in a significant deterioration of secretariat and overall system performance, leading to the conclusion that clerical staff reduction will only come with a cost in quality.

Table 5 Main performance changes

Simulation Object	Performance Measure	Scenario 2	Scenario 3
Secretariat Queue	Average Queue Size	0.12	1.61
	Average Time in Queue	0.34	4.62
	Average Queue Size (excl. zero times)	1.23	6.86
Pronouncement Queue A	Average Time in Queue	0.31	1.57
Pronouncement Queue B	Average Time in Queue	3.78	5.28
Exit	Average Time in System	23.38	28.96

Table 5 contains a set of the most vital changes in performance since the staff reduction. Almost all secretary-related activities suffered significant change. It is noted that the average time in system was increased by 5.58 minutes. The biggest share in this increase is caused by the increased average time in the secretariat queue (4.28 minutes average increase).

7.5 Reporting of the results

The results were presented to the management and they were accepted as rational and extremely helpful. The company implemented the study's main suggestion and did not reduce its staff. A follow-up simulation study will assess the new center when it will be fully and regularly operational to validate initial findings and further assist the company's operational decision making.

8 Conclusions

The experience gained by this study outlined a number of advantages of the discrete event simulation method in health care decision making and management. Simulation provided a relatively low cost / budget method that allowed the study team to gain a detailed understanding of the operation of the diagnostic center, experiment with what' if scenarios that can save cost and valuable time. The team was able to assess the operational status of the old center, measuring efficiency of key cost centers (i.e. resources), and make validated predictions about future center's situations.

Simulation offers a win-win scenario to the health provider stakeholders and health care seekers. Operational management gets insight about its own operating system and is able to get results out of hypothetical questions. Corporate management is provided with a powerful tool to assess the operational management efficiency, and to take better decisions about operational issues that would be hard to analyze through conventional managerial methods. Quality of Service and cost-control are made easier to understand and to manipulate, with the final results benefiting the final user as well as the organization's performance.

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