22nd *International Conference on Modelling and Applied Simulation*
20th International Multidisciplinary Modeling & Simulation Multiconference

2724-0029 © 2023 The Authors.
doi: 10.46354/i3m.2023.mas.009

Simulation the customer service capacity in a dental clinic

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Abstract

The purpose of this paper is to investigate the service delivery system of a dental clinic in Mexico City to maximize the clinic's efficiency. The study uses process analysis to determine the capacity utilization and areas of bottlenecks in the dental clinic's system. The main objective of this study is to generate an optimum solution for capacity planning and appointment scheduling issues, which are frequently encountered in clinical flows with various route and treatment periods at dental hospitals. Regarding hospital management quality, the most important ones of these factors are accurate calculation of appointment capacities, and the assignment of proper staff number at the proper departments with optimum scheduling. This model helped evaluate the performance of the clinic using patient arrivals and consultation times as input parameters.

Keywords: Simulation; Patient flow, Custom service, Appointment scheduling, Time.

1. Introduction

In Mexico, nearly 95% of all enterprises are classified as PYMES (Small and Medium-sized companies), and an alarming 75% of these establishments cease operations within the first two years. This detrimental trend also affects service-oriented businesses.

Hence, we are keen to showcase the tangible outcomes of our efforts within one such company, emphasizing our ability to not only bolster their financial standing but also enhance the quality of service their customers receive.

The Fabrica de Sonrisas dental clinic, located in Mexico City, grapples with significant obstacles in its appointment scheduling process. The clinic recognizes that patient satisfaction and favorable medical outcomes hinge upon the prompt and effective delivery of care. Regrettably, extended waiting times persist as a common source of patient dissatisfaction, often arising from operational inefficiencies or an overwhelming demand that surpasses the clinic's capacity.

The primary objective of this paper is to examine the appointment scheduling practices implemented at the Fabrica de Sonrisas dental clinic, with a specific focus on identifying the underlying causes of direct and indirect appointment delays. By doing so, we aim to optimize clinic productivity and enhance overall efficiency. Nonetheless, attaining these objectives poses a formidable challenge, given the multifaceted factors that influence clinic performance.

Various parameters contribute to the intricacies of clinic operations, such as punctuality among patients and care providers, variations in consultation durations, availability of resources, and the unpredictability associated with walk-in appointments, including emergencies. These parameters collectively influence the clinic's performance, making it imperative to address them comprehensively in our analysis.

This research paper aims to delve into the appointment scheduling practices employed at the Fabrica de Sonrisas dental clinic, with a specific emphasis on identifying both direct and indirect causes of appointment delays. Our primary objectives revolve around maximizing clinic productivity and efficiency. However, achieving these goals poses a significant challenge due to the diverse array of parameters that influence clinic performance.

Factors such as patient and care provider punctuality, variations in consultation times, resource availability, and the unpredictable nature of walk-in appointments, including emergencies, all contribute to the intricate web of clinic performance determinants.

The central challenge we encounter in this study is comprehending the underlying causes of delays throughout the clinic while implementing corrective measures without inadvertently exacerbating other issues. Given the interdependence among these various factors, isolating a single problem for independent resolution becomes arduous. Instead, we must adopt a comprehensive, system-wide approach to enhance scheduling practices and optimize overall clinic performance.

2. State of the art

Appointment scheduling is a complex and vital component of healthcare services, mirroring its significance in other service industries. The initial appointment system, introduced in 1952 based on Bailey's and Welch rules, replaced the previous first come, first served approach in patient treatment. Over time, this system has evolved to meet the growing demands of patients, encompassing block scheduling, individual appointments, and same-day availability.

However, with the surge in population, advancements in medicine, and increased accessibility to medical resources, the scheduling process has become more intricate. As healthcare costs escalate, providers are compelled to enhance the efficiency and productivity of their clinics within existing resources. The ultimate objective of an appointment system is to strike a balance between patients' waiting time, doctors' idle time, and overtime.

Extended waiting periods and a dearth of timely appointments significantly contribute to patient dissatisfaction. Inefficient resource utilization, prolonged work hours, congestion near facilities, and lengthy queues can diminish overall productivity, posing concerns for healthcare providers. In addition to addressing these challenges, it is important to consider the impact of appointment scheduling on the profitability and quality of service of healthcare businesses.

From a profitability perspective, efficient appointment scheduling is essential for maximizing revenue generation. By optimizing the utilization of resources and minimizing idle time, healthcare providers can effectively manage costs and improve the financial performance of their clinics. Moreover, satisfied patients who experience shorter waiting times and prompt access to services are more likely to become loyal customers, resulting in increased patient retention and potential referrals, which further contribute to profitability.

In terms of quality of service, appointment scheduling plays a crucial role. A well-designed and executed scheduling system allows healthcare providers to allocate sufficient time for each appointment, ensuring that patients receive the attention and care they deserve. By avoiding rushed appointments, healthcare providers can enhance the quality of the service delivered, leading to higher patient satisfaction, improved health outcomes, and a positive reputation for the clinic.

Furthermore, efficient scheduling helps manage customer expectations and enables personalized service. By collecting and utilizing patient information during the scheduling process, healthcare providers can tailor their services to meet individual needs and preferences, thereby enhancing the overall patient experience.

In summary, efficient appointment scheduling in healthcare is not only vital for balancing patient waiting time, doctors' idle time, and overtime, but it also has a significant impact on the profitability and quality of service of healthcare businesses. By optimizing resource utilization, maximizing revenue potential, and delivering personalized care, healthcare providers can achieve both financial success and exceptional service, leading to satisfied patients and a thriving business.

2.1. Model parameters

a. Patient arrivals:

In modeling outpatient clinics, several input parameters are considered, including patient arrivals, which encompass factors such as patient punctuality, appointment cancellations, no-shows, and the number of walk-ins or emergency cases. These parameters have a significant impact on patient wait times, idle time, and overtime for both patients and doctors.

Patient punctuality: Punctuality refers to the extent to which patients arrive on time for their scheduled appointments. While the importance of patient punctuality in outpatient clinic scheduling is widely acknowledged, only a few studies explicitly incorporate this parameter into their models.

Appointment cancellations and no-shows: Appointment cancellations occur when patients notify the clinic in advance that they won't be able to attend their scheduled appointments. On the other hand, no-shows refer to patients who fail to appear for their appointments without any prior notice. These factors can significantly impact clinic operations and patient scheduling. While there is a scarcity of studies specifically addressing appointment cancellations, various studies include the no-show rate as a fixed value ranging from zero to 20 percent.

Walk-ins and emergency cases: Walk-ins are patients who visit the clinic without a prior appointment, while emergency cases require immediate attention. These arrivals are often difficult to control or predict, adding an element of uncertainty to the scheduling process. Most studies acknowledge the existence of walk-ins and emergency cases, but their impact is typically limited and unpredictable. Therefore, incorporating them into scheduling models can be challenging.

b. Patient classification:

Patients visiting outpatient clinics exhibit variations in terms of service time characteristics, diagnosis, and urgency. Classifying patients based on these factors can assist schedulers in adjusting appointment sequencing and intervals accordingly. Additionally, patient classification can be based on whether they are new or returning patients, as their service times and check-in times may differ.

While patient classification is acknowledged in the literature, its application in scheduling models varies. Some studies focus on service time characteristics as the primary basis for patient grouping, allowing for customized sequencing and appointment intervals. Others consider the distinction between new and follow-up patients, accounting for variations in service times and check-in times. Another approach involves grouping patients based on diagnosis, enabling more specialized assignment of patients to specific doctors or departments.

c. Service distributions:

In outpatient clinic modeling, the service time required for consultations with care providers is typically represented using continuous probability distributions. A variety of distribution types have been employed in the literature, each with its own characteristics. Some commonly utilized distributions include Gamma, lognormal, Weibull, uniform, and (negative) exponential distributions.

The choice of service time distribution depends on factors such as the nature of the service being provided, the available data, and the goodness-of-fit to empirical observations. Some studies fit these distributions to empirical data, allowing for a more accurate representation of service times. The selection and fitting of appropriate service time distributions are crucial for accurately modeling patient flow and resource allocation in outpatient clinics.

It is worth noting that the choice of distribution and its parameters can greatly impact the performance of scheduling models, including patient waiting times, utilization of resources, and overall clinic efficiency.

d. Care provider allotment:

A common characteristic observed in many studies on outpatient scheduling is the restriction of models to a single care provider with a single queue. However, there are exceptions to this approach.

In these cases, patients were typically scheduled in a single queue and assigned to the first available doctor upon arrival. Although incorporating multiple care providers can introduce complexities in terms of resource allocation and sequencing, it can more accurately reflect real-world scenarios in outpatient clinics where multiple doctors or specialists are available.

2.2. Simulation

This section provides an overview of the input parameters utilized for modeling the outpatient clinic and appointment suggestions, based on previous research studies. The parameters related to patient arrivals encompass factors such as patient punctuality, appointment cancellations, no-shows, and the presence of walk-ins or emergency cases that are beyond the control of the clinic. These variables significantly influence patient wait times, idle time, and overtime for both patients and doctors. However, it is worth noting that while punctuality has been considered in only a limited number of studies, no research has been found that incorporates appointment cancellations. The rate of patient no-shows is typically treated as a fixed value in most studies, ranging from zero to 20 percent. In some investigations, the occurrence of no-shows has been stochastically modeled using a uniform distribution. Emergency walk-ins, on the other hand, are unpredictable and occur in limited numbers.

Patients exhibit variations in terms of service time characteristics, diagnosis, and urgency. The classification of patients based on service time characteristics allows the scheduler to adjust the sequencing and/or the appointment interval accordingly. Patients can also be classified as new or returning based on their visit to the clinic. Service times and check-in times differ between new and follow-up patients. Another possibility is to group patients based on their diagnosis, and this classification can be utilized when assigning patients to specific doctors.

The service time for consultations with care providers is represented using continuous probability distributions, with a wide range of distributions being commonly employed, including Gamma, lognormal, Weibull, uniform, and (negative) exponential distributions. Some of these distributions are fitted to empirical data.

Most studies on outpatient scheduling focus on a single care provider with one queue. There are a few exceptions, such as the work of Fetter and Thompson (1966), who scheduled patients for three doctors, and the simulation model developed by Liu and Liu (1998), which incorporated two to five doctors. In both cases, patients were scheduled in a single queue and assigned to the first available doctor upon arrival.

3.0 Problem Description

Capacity can be defined as the maximum output rate achievable by a facility. Capacity planning in a company is typically conducted at two levels, corresponding to strategic and tactical decisions.

The strategic level of capacity decisions pertains to long-term planning. It involves determining the investments in new facilities and equipment that a company should undertake.

On the other hand, the tactical level of capacity decisions focuses on short-term considerations, such as workforce planning, inventory management, and day-to-day machine utilization.

Capacity planning assists businesses in budgeting and scaling operations, allowing them to identify optimal levels of operations. It helps determine how services are offered, the appropriate time frames, and the necessary staff to meet current demand and cover operational costs. Accordingly, the main objectives of this paper are to study appointment scheduling at the dental clinic, identify the causes of direct and indirect delays in appointments, and maximize the system's productivity.

The primary challenge of this study lies in maximizing the overall revenue of the dental clinic by comprehending and defining the capacity of its facilities and exploring potential solutions. These challenges are compounded by variations in the efficiency and scheduling of dentist office times, as well as the arrival patterns of patients.

4. Methodology

Following the framework outlined in "How to Build a Valid and Credible Simulation Model" by Avery M. Law, the next steps in the process after describing the problem would be as follows:

Collect Data: This step involves gathering the necessary data to populate the simulation model. This includes collecting information on patient arrivals, service times, appointment cancellations, no-show rates, walk-ins, and other relevant parameters. Additionally, data on clinic operations, resource utilization, costs, and any other factors that impact the system being modeled should be collected.

Define Assumptions: Assumptions play a crucial role in simulation modeling as they help define the boundaries and conditions under which the model operates. It is important to clearly specify any assumptions made during the model development process. These assumptions can include factors such as patient behavior, resource availability, system constraints, and any simplifications or approximations made to facilitate the modeling process.

Program the Model: Once the data is collected and assumptions are defined, the next step is to program the simulation model. This involves translating the problem description, data, and assumptions into a computational model that can simulate the behavior of the system. The programming language and software used for modeling may vary depending on the specific requirements and available resources.

Validate the Model: Model validation is a critical step in ensuring the accuracy and credibility of the simulation model. It involves comparing the model's outputs with real-world observations or benchmark data to assess its performance. Validation may include conducting sensitivity analysis, running various scenarios, and comparing the model's results with historical data or expert opinions. If the model fails to accurately represent the real system, adjustments and refinements should be made until an acceptable level of validation is achieved.

To start with the analysis, information was gathered physically in the dental clinic. Processes, cost, and patient appointments were gathered to help define variables and trends.

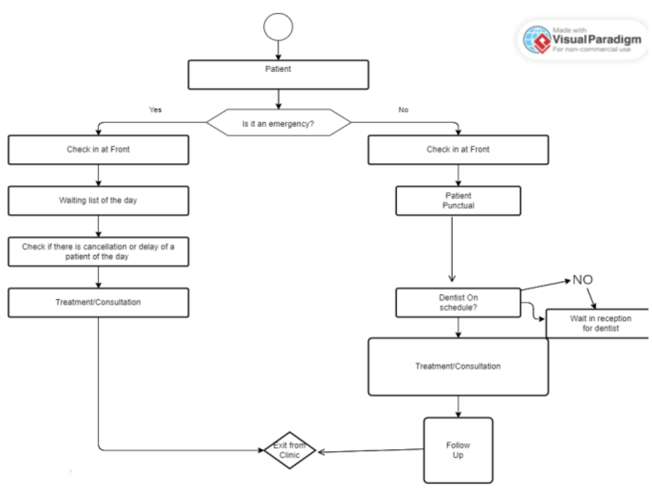

Figure 1: Process flow diagram of Dental clinic

4.1. Resources

There are several human and physical elements at the dental clinic to cope with this process, which are:

- 4 Consulting rooms General Dentistry
- 1 Front desk
- 1 Receptionist
- 4 Sitting space in the Patient waiting room.
- 4 Specialist dentist

4.2. Variables and Key Performance Indicators

The variables considered are as follow:

<u>Input</u>

- Customer services done by type and service.
- Weighted avg Customer Ticket
- Weighted avg service time

<u>Decision variables</u>

- Customer Service
  - Actions aimed to improve customer experience.
- Sales Effort
  - Offer of incentives to improve patients' arrival flow.
- Process Improvement
  - Time efficiency strategies to improve time allocation through appointments & services optimization.

<u>Output</u>

- Patients Arrival
  - Impact through customer service activities.
- Capacity Utilization
  - Target to improve though optimization services.
- Customer Satisfaction
  - Aimed to gains good reviews in Google Reviews
- Revenue
  - Improve Revenue by increasing arrivals & capacity.

4.3. Data collection and analysis

Data collection plays a crucial role in

acquiring a quantitative comprehension of the various parameters involved. Additionally, it serves as the primary input source for the subsequent development of simulation models.

To gather the necessary data, time studies were conducted over several days. These studies encompassed the collection of information such as appointment times, appointment durations, average times for each service, and associated costs within the clinic.

To establish a weighted average service price, we conducted an analysis utilizing 16 months' worth of collected data.

Regarding the services offered, we have categorized them into three main categories, outlined as follows:

CATEGORY	*AVG PRICE*	*PLANNED TIME*
SURGERY	$20,897	120
ORTHODONTICS	$830	60
MEDICAL CONSULTATION	$1,327	60
TTL	**$ 4,130**	**69**

The patient's arrival volume by categories show a clear difference between the costly Surgery procedures and the common medical consultation

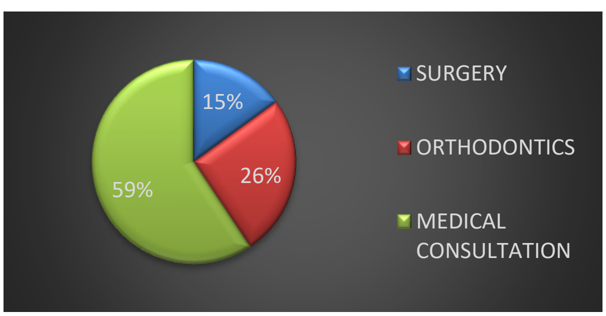

Figure 2: Total Study Procedures Mix

Weekdays were also analyzed by category and the following data was estimated (Sundays, the clinic do not work)

DESCRIPTION	Mo	Tu	We	Th	Fr	Sa	TTL
SURGERY	120	145	138	93	116	99	711
ORTHODONTICS	227	296	308	127	91	170	1,219
MEDICAL CONSULTATIONS	558	466	534	371	407	482	2,818
TTL	**905**	**907**	**980**	**591**	**614**	**751**	**4,748**

Table 1: Total Services by Category

DESCRIPTION	L	MA	MI	J	V	S	TTL
SURGERY	13%	16%	14%	16%	19%	13%	15%
ORTHODONTICS	25%	33%	31%	21%	15%	23%	26%
MEDICAL CONSULTATIONS	62%	51%	54%	63%	66%	64%	59%
TTL	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Table 2: Total Services by Category (Mix)

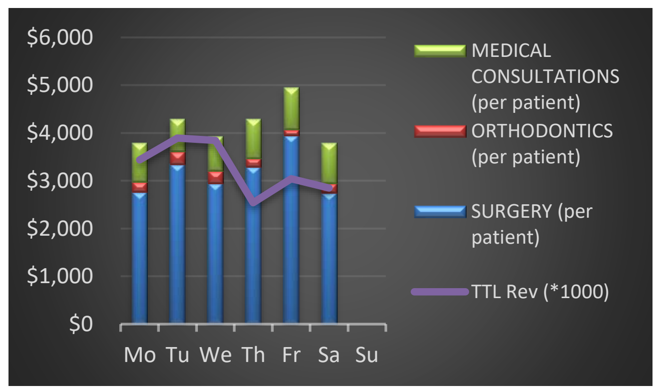

Figure 3: Revenue by category

Therefore, Friday is the day with the highest revenue per patient arrival but one of the lowest on total day revenue.

4.4. Assumptions

For this simulation, it was necessary to make some assumptions to justify the way in which we developed the simulation of our process. The assumptions made are the following:

- All doctor offices are available for any patient and procedure required.

- Weekdays show different behavior. No monthly stationarity was established.
- Service appointments are programmed rounded to the next hour (for example, 40 minutes consultations are programmed for 60 minutes in the agenda)
- Current Google Rating of the clinic is 4.5 stars
- No incentive was considered for the original data analysis.
- Sales effort Impact was established at 15% using elasticity impact (e=-3) with a 5% incentive.

DESCRIPTION	REAL	IMPROVEMENT	Δ
Price	$ 4,130	$ 3,923.19	-5.0%
# Services	12	$ 14.29	15.0%

Table 4 *Estimated impact in price & service quality*

- Process improvement was established at 15% targeting a 60-minute avg patient time.

DESCRIPTION	REAL	IMPROVEMENT	Δ
Daily Service Minutes (10 hour service)	600	600	0.0%
# of Doctor Offices	4	4	0.0%
Weighted avg service Time	69	60	-13.0%
Appointment Capacity	35	40	15.0%

Table 5 *Estimated impact Estimated impact in Office efficiency*

- Quality improvement (+1pp in google reviews) is defined as 10% of patients increase.
- Maximum Clinic capacity is established at 30 patients using avg figures.

4.5 Program the model

Forio Epicenter (forio.com) is a versatile platform that can be used for a wide range of simulation purposes, including discrete event simulation. With its user-friendly interface and powerful features, it allows developers to build simulations that model complex systems and processes, such as supply chains, manufacturing processes, and logistics networks.

By using discrete event simulation techniques, Forio Epicenter can simulate the behavior of a system over time, considering various events that can occur.

This can help users better understand how different factors can impact the performance of a system, and to test different scenarios to identify opportunities for optimization and improvement. Overall, Forio Epicenter provides a powerful framework for creating and running discrete event simulations, helping organizations make better data-driven decisions.

Our team developed a simulation which can be found on this link:

forio.com/app/silega/dental-clinic-simulation

The simulation included the following interface tabs:

- General information.
- Dashboard to visualize results.
- Decision where different input variables can be manipulated.
- Run Manager where previous runs can be administered.

Figure 4: Simulation Introduction

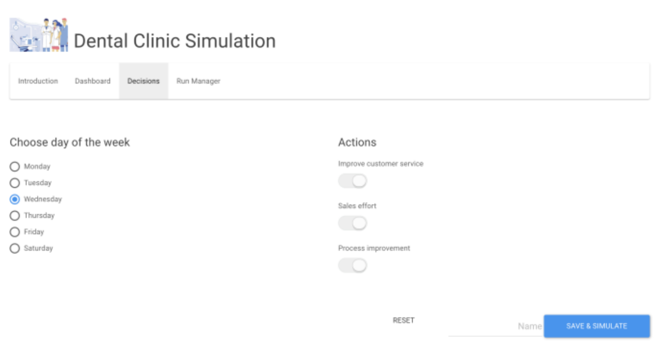

Figure 5: Simulation independent variables

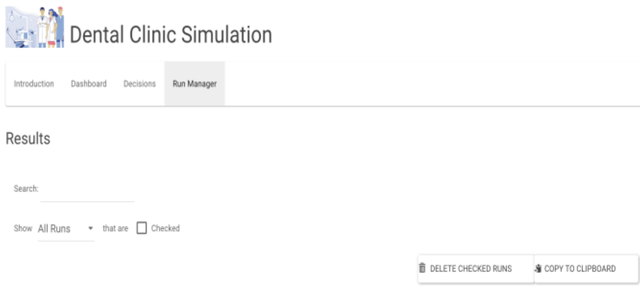

Figure 6: Simulation results

4.6 Model Validation

Our team has successfully completed simulation model validation, a crucial step in the simulation development process. We compared the output of our simulation model with real-world data to ensure its accuracy and reliability. By collecting data from the real system and running our simulation model with that data, we were able to identify any discrepancies or errors that may have existed. After comparing the results to the observed data, we confirmed that our model accurately captures the relevant features of the system being modeled, and the model output matched the observed data within an acceptable range of error. The completion of simulation model validation assures that our simulation models are trustworthy and can be used to support data-driven decision-making processes.

4.7. Simulation Model

The model was developed to be compatible with Forio's Simlang programming language. The program simulates 60 discrete steps in a single working day and user can choose which day to simulate.

4.7.1. Base model

A simulation baseline model was a simplified version of a simulation model that served as a starting point for further development and refinement. It typically included the most essential components and assumptions of the system being modeled, while omitting or simplifying more complex aspects. The purpose of a baseline model was to establish a foundation for the simulation model that could be built upon and tested against actual system performance data. It could also serve as a benchmark for comparing different simulation scenarios or models. The development of a baseline model typically involved identifying the key variables and relationships of the system being modeled and constructing a simple mathematical or logical model that captured the most important dynamics. The baseline model was then refined and validated through sensitivity analysis, calibration, and comparison to real-world data.

For example, first a typical Wednesday is simulated.

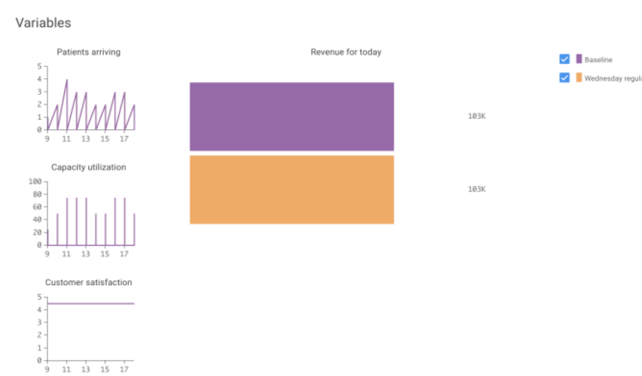

Figure 7: Simulation example output

4.7.2. Simulation model scenarios

Then, we simulated a Wednesday with the following changes:

- Improved sales effort to attract more patients.
- Improved customer service and word of mouth.
- Process improvement to increase the capacity utilization.

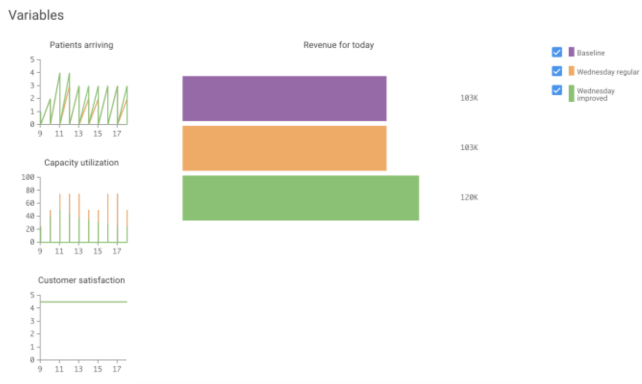

Figure 8: Simulation example output impact

5. Results

The simulation calculates the increase in patients flow and increased revenue, plus increased capacity utilization.

6. Conclusions

The simulation gave us interesting information. Revenue is heavily impacted by the suggested actions. We saw that the clinic capacity is highly underused on most days (considering a top 30 patients' max capacity).

DESCRIPTION	Mo	Tu	We	Th	Fr	Sa
TTL	905	907	980	591	614	751
TTL Weekday	69	69	69	69	69	70
Visits per Day	13	13	14	9	9	11

Table 6 *Assistance by timeframe*

Therefore, we are purposing a 3-step plan to increase revenue by impacting the patients' arrivals:

1) Add incentives to increase patients flow into the clinic.
2) Consider making process efficiencies through appointment & procedures efficiencies targeting time-out avoided.
3) Improve google Reviews to reach better customer experience through less time expending procedures and results.

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