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Optimizing OR Efficiency through Surgical Case Forecasting with ARIMA Averaging

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Abstract

Operating rooms, often known as ORs, are among the most critical parts in hospitals, and their performance has a considerable bearing on how well the hospital functions as a whole. Uncertainty contributes significantly to the difficulty of an operating room. Credible forecasts are essential for operating room efficiency because they can provide signals for the monitoring of surgical overflows in periods of peak and trough demand for surgery; and minimize the related costs in equipment and workforce redundancy, and improve overall health care services. Optimizing the efficiency of the operating room has significant consequences for cost reductions, patient happiness, and the morale of the surgical department. Forecast averaging, also known as prediction combining, is a system for merging several predictions into a single prediction, which is often a better way than deciding which one forecast was best out of the available individual predictions. We applied the ARIMA Forecast Averaging method to demonstrate the surgical volume case predictions. We also showed that in forecasting surgical volume cases, the ARIMA models with lower AR and MA terms performed well in terms of different model selection criteria such as AIC. BC, and HQ. Medical care service problems are caused not just by a mismatch between resource demand and supply, but also by poor management. Operating rooms requires a significant investment of both time and money. Ineffective usage of operating rooms results in lost efforts and time, increased expenses, and a lower number of patients treated compared to what was originally anticipated. This cluster of problems leads to losses as well as a reduction in the level of satisfaction experienced by patients. We argued that the cost of usage of the operating room (OR) may be significantly decreased by increasing the predictive accuracy of the surgical case volume.

Keywords: Automatic ARIMA, Healthcare, Operating room, Surgical volume, Forecast

Introduction

The operating room is one of the most important and costly resources in a hospital. The operating theatre is both an expense and a profit generator. Many hospitals are interested in increasing the productivity of their operating rooms. The hospital administration seeks to increase overall operating rooms performance in terms of resource usage, production volume, and cost reduction. Other stakeholders see various issues around the operating rooms. Actual surgery length varies greatly, resulting in varied daily demands for OR employees. Some surgeons worry for not being ready to do as many procedures as they would want. Surgical wards see high changes in patient flow, resulting in poor average bed occupancy and frequent overstaffing and understaffing. operating rooms planners have the weekly problem of creating a practical and appropriate OR schedule while taking into consideration a plethora of limits, interests, and goals [1], [2].

Surgeons attempt to complete as many planned operations as they can in a given day, in a predefined sequence. Furthermore, there is a high demand for emergency surgery practically each day, and surgeons aim to operate on these medical emergencies as quickly as possible due to their urgent state. If an emergency operating room is available, patients are usually sent there right away. If the emergency operating room is full, the emergency inpatient is treated in facilities according to the specialty to which the patient or the required procedure belongs. As a consequence, certain planned inpatient and outpatient procedures may have to be rescheduled or postponed. Furthermore, procedures planned for the evening, for example, may not be done since they are too far behind schedule and cannot be finished within the staff hours if begun [3], [4].

Unpredictability accounts for a significant portion of an operating rooms' overall complexity. The operating room is a complicated setting that features social interactions on several levels, an unpredictable nature, a limited tolerance for errors, and high expectations. The amount of time and effort needed to complete a surgical operation is one of the factors that determines how efficient a process is. It is common practice for hospitals to monitor this in order to ascertain patient anesthetic durations, OR turnover times as well as rates, and case volumes [5], [6]. In light of the fact that they have a certain amount of time to devote in the operating room, surgeons place an emphasis on operating room efficiency in order to provide the highest possible level of care to the greatest number of patients.

Studies have discovered that focusing on a select few important areas helps increase their overall efficiency. These areas include, but are not limited to, the following: a) Time management which entails maintaining a day that is correctly organized and adhering to established start timings. Business) Utilization of resources which includes having all of the necessary supplies and team members available in the operating room. c) Reducing the number of unused supplies in the operating room to ensure minimal waste. d) Process optimization which refers to having a team that is properly coordinated while the operation is being performed. While it is generally agreed that achieving these objectives would be helpful, it is not always obvious how to do so in a way that maximizes efficiency. Because of this, people are need to put in longer hours at work and take on more responsibility in order to compensate for the inefficiencies [7], [8].

The flow of patients to hospitals should be analyzed so that possibilities for strategic cost control may be explored. The creation of a uniform method for the movement of patients across a hospital has the potential to save expenses while also improving the level of care that these patients get. When patient flow is optimized, it helps to reduce long waits, optimize room cycle time, save staff resources, and guarantee that every hospital bed is occupied to its fullest capacity.

Standardizing patient flow in hospitals may be accomplished in part by forming partnerships with companies that specialize in patient transportation. This investment eliminates bottlenecks and contributes to maintaining a steady flow of patients, which, in the end, lowers total expenses while increasing patient satisfaction.

Waits, delays, and cancellations are already so frequent in the healthcare industry that patients and clinicians feel waiting is an essential, but unfortunate component of the treatment process [10]. Certain aspects, such as streamlining the process of elective surgery, shortening the wait times for hospitalization through emergency services, and enhancing the flow of patients from the inpatient facility to long-term care facilities are among the specific areas of research interest [11]. The movement of patients through hospitals may be standardized, which is an excellent approach to both save expenses and enhance the quality of treatment provided. Hospitals are able to reduce the number of delays for patients as well as ensuring that each bed is occupied to its fullest capacity if they optimize patient flow and keep devoted personnel and resources intact [12], [13]. [14].

Hospitals that have developed effective methods for the scheduling of staffs and equipment's are better able to accommodate last-minute adjustments and remain in line with applicable rules. Additionally, it guarantees that communication between workers and between employees and schedulers is done in an efficient and easy manner [15].

Because of the high levels of stress in the healthcare profession, it is extremely crucial to ensure that employees are engaged in their work and satisfied with their jobs. As a nurse, one is required to perform long hours and often face difficult circumstances. They are more likely to experience weariness, burnout, and unhappiness with their jobs. One of the potentially disastrous effects that all of these variables may have is a decline in the standard of the treatment provided to patients [17], [18].

It may be difficult to lower labor expenses while keeping staffing levels at an acceptable level and preserving the quality of patient care. While making sure that all duties are completed, schedulers have the responsibility of preventing needless overtime and allocating time for breaks. A management may estimate demand and labor demands focusing on historical data in order to optimize labor expenditures and establish schedules that are efficient with regard to cost [19]. A typical tactic is to spend in advanced ways to retain employees in order to decrease expensive staff turnover. A procedure for scheduling nurses that is effective will need to take all of these considerations into account [20], [21].

The identification and treatment of diseases are just two aspects of medical care; there are many other aspects as well. It is costly to construct and equip hospitals, and it is also expensive to maintain hospitals. As a result of the transition toward more modern diagnostic and treatment capabilities, hospitals are required to make significant investments in resources and to manage those resources in a responsible manner. The difficulty comes in efficient usage of limited resources, effective medical care provision, and effective planning and execution.

The shifting financial structure, which is geared toward privatization and competition, puts pressure on health-care organizations, especially hospitals, to enhance efficiency and productivity. Simultaneously, the quality of hospital treatment is getting more transparent for patient, lawmakers, and society as a whole, thanks in part to a number of monitoring efforts. Hospital administration is under pressure to increase both cost effectiveness and excellence of treatment. These aims are often incompatible [22], [23].

The Operating Room, or OR, is a spacious, clean room where doctors perform surgical procedures on patients. It is outfitted with surgical tables, scanners, and other surgical equipment. Depending on the kind of operation, there are several types of operating rooms. Rooms for specialties such as general surgery and gynecology Hybrid theaters in which surgery and imaging may be merged, as well as operating rooms outfitted with robots for robot-assisted surgeries. The air is antiseptic and clean, and the space is usually calm and silent. The operating room also has several high-tech devices and equipment. Most operating rooms include laparoscopic devices, diathermy hardware, an operation table, and suction [24], [25].

The operating room (OR) personnel or surgical team will begin the patient's care when a surgical operation is necessary. The operating room crew is responsible for providing care and support to the patient during the surgery. The operating room professionals share responsibility for the patient's wellbeing and comfort. Everyone on the surgical team plays a specific duty in the operating room and prioritizes the wellbeing of all patients. During surgical procedures, a group of medical professionals assists the surgeon. The number of staffs on the surgical team varies based on the type of procedure. The majority of teams consist of the following experts:

A surgeon is the surgical team's leader. It is the surgeon's obligation to guarantee that the procedure runs well and without difficulties. The surgeon leads all nurses and helpers during the process, while collaborating with the anesthesiologist to control the patient's care and condition. While certain procedures may need a surgical team, the typical surgical team consists of a single surgeon and one trainee surgeon [27], [28].

A surgeon has completed four years of medical school as well as at least four years of specialized training following graduation. The vast majority of surgeons have completed certification tests. In the United States, this qualification for general surgery is issued by the American Board of Surgery, a national organization. Some surgeons furthermore have the initials FACS after their names. This indicates that they have the approval of

Anesthesiologists work to guarantee the safety of surgical patients. The anesthesiologist cares for the patient in order to keep them from feeling pain. Surgeons and anesthesiologists collaborate to provide the greatest possible results for patients. The ability of anesthesiologists and surgeons to collaborate is crucial to patient safety. An anesthesiologist has completed four years of medical school in addition to four years of specialized training in anesthesia. Anesthesiologists may get further training in certain surgical subspecialties. This might pertain to neurosurgical or cardiac anesthesia. Before, throughout, and after the surgical procedure, the anesthesiologist is present [29], [30].

Anesthetist nurse practitioner certified (CRNA) is also included in the tam. Prior, during, and following surgery or childbirth, the nurse anesthetist administers anesthetic treatment. Every vital bodily function is regularly monitored by the nurse. To ensure your safety and comfort, he or she might modify the anesthetic medication. A nurse anesthetist possesses a bachelor's degree in nursing and one year of training as a registered nurse in a critical-care environment. A master 's certificate from a nurse anesthetist school is also required. CRNAs must complete a national certification test in order to practice as nurse anesthetists. Nursing staff are recognized and certified by each state to provide patient care. Certain nurses specialize in an area, such as surgery. The surgical nurse assists the surgeon throughout the procedure. The certifications of operating room nurses span several surgical specialties [31], [32].

By preparing a sterile operating area, surgical technologists aid in the procedure. They prepare surgical materials and supplies. In addition, they provide the surgeon with the required instruments. National Board of Surgical Assisting certification requires them to pass an exam (NBSTA). In several teaching hospitals, resident physicians in training and medical graduates may be part of the surgical team. Under the supervision of a physician, physician assistants practice medicine. They may serve as a surgical assistant. Alternatively, incisions may be closed using stitches (sutures) or staples. Occasionally, surgeons will also have a consultant from a firm that manufactures medical devices in the operating theatre. Artificial limbs, spine supports, and pacemakers are examples of such devices. The representative is able to assist the surgeon with the sizing and operation of the equipment [34]–[36].

Problem statement

Hospitals are coming under growing financial strain from a variety of sources, including rising levels of competition, poor payer mix, and other issues. As a result of these demands, lower costs and control are at the forefront of the thoughts of those in charge of healthcare finance, regardless of whether the organization in question is rural, nonprofit, urban, or part of a safety-net system. The healthcare sector is one of the most labor-intensive industries. The spectrum of people required in the operation of a hospital is extensive, ranging from highly qualified physicians and technicians to nurses or general duty assistants [37], [38].

In a healthcare system, the efficiency of the operating room (OR) can be affected by a wide variety of factors, such as the expectations and satisfaction of patients, the interactions between various professional specialties, the uncertainty of operations, the scheduling of surgical cases, and so on. The operating room (OR) procedure is complicated and includes a number of different parties; nonetheless, one method to improve the efficiency of the OR is to improve the accuracy of the estimated surgical case length. When operating room (OR) time is over- or under-utilized, it frequently results in unfavorable implications such as wait time, extra hours, postponement or delaying of surgeries, all of which have the potential to have a serious affect on the patient, hospital staff, and the institution as a whole.

It is necessary to have accurate projections of the daily surgical volume in order to improve the efficiency with which one uses this limited and expensive nursing resource. The number of occasions a certain surgical operation has been performed at a hospital during a given period of time is referred to as the surgical volume for that facility. Because choices on staff scheduling are often made several weeks in advance, Fluctuation in daily surgical case load leads to a suboptimization of the resources that are allocated for the day of surgery. In most cases, management will prepare for the highest possible demand by assigning personnel to each of their available operating rooms (ORs). As the day of surgery draws near, management may strive to shut operating rooms (ORs) that do not have any booked cases or merge ORs that have very few cases, creating an opportunity to lower the staff labor expenses associated with operating rooms [39], [40].

Methodology

Multiple studies (Timmermann, 2006) have found that averaging predictions is more appropriate than selecting the best single forecast. Prediction averaging, also known as forecast combining, is a technique for merging many forecasts into an one forecast, which is often preferable than selecting the "best" of the available individual forecasts.

ARIMA

A time series variable such as surgical volume, x_t, is considered to be an $ARIMAX(p, d, q)$, if,

$$D(x_{1t}, d) = \beta x_2 + v_t$$

Where,

$$v_t = \gamma_1 v_t + \gamma_2 v_{t-1} + \cdots + \gamma_p v_{t-p} + \delta_1 \epsilon_{t-1} + \cdots + \delta_q \epsilon_{t-q}$$

AR and MA term sizes may be computed in a number of methods, one of which is through model selection/evaluation techniques.

ARIMAX systems may be evaluated in a number of methods, including by transforming the equations into a non-linear equations or by utilizing GLS or ML estimation. Because ML estimation does not need data removal from the beginning of the dataset or backcasting to produce new data, it lends itself perfectly to model selection/comparison procedures. [41], [42].

Model Specification

The process of developing the ARIMAX model for predicting a surgical volume may be broken into four steps:

1. Selecting any dependent variable changes, which includes logarithmic transformation.

2. Establishing the degree of differentiation of the response variable.

3. Select the exogenous regressors.

4. Order of the ARIMA parts.

The conversion of the response variable is often selected in line with a theoretical framework. The most common transformations are logs and the Box-Cox transformation. It may, however, be able to determine whether or not to capture logs by using a rule-of-thumb technique that entails conducting two fundamental regressions:

This test is widely used on variables whose rate of variation in growth grows or falls exponentially over time. When such data are used in a least squares estimation with differences, heteroskedasticity occurs. The link is linearized by transforming to logs, which eliminates the problem of heteroskedasticity.

Differencing

The second step is to identify the optimal degree of differentiation for the response variable (that may have been transformed). Computer programs calculates the appropriate degree of differentiation via recurrent unit root testing. When forecasting, HK suggests under-differencing rather than over-differencing the model. As a consequence, HK proposes doing a unit-root test, including the KPSS test, comparing the null hypothesis of no-stationarity. Initially, no differences are made in the KPSS assessment of the data. If the test rejects the null hypothesis, differencing is conducted as well as the KPSS test is reapplied. This technique is continued until the null hypothesis cannot be rejected any longer. [43], [44].

ARIMA selection

Model selection is used to identify the best ARMA order. Model choosing is a strategy for determining which kind of model best matches a given set of data, and it is usually used to pick the best model to use to forecast that data.

The information criteria is the most commonly employed model selection strategy in data science literature. We can estimate three types of information criteria for the majority of estimation techniques: the Akaike Information Criterion (AIC), the Schwarz Criterion (SIC or BIC), and the Hannan-Quinn Criterion (HQ). Each of these criteria is decided by the estimated log-likelihood of the model, the number of parameters in the model, and the number of occurrences.

Measuring the Mean Square Error (MSE) The second method of model selection is in-sample forecast evaluation. Each model is built using a subset of data and then projected over the remainder datasets. By comparing the forecasts to the actual data during the subsample forecast period, we can calculate the mean square error (MSE)[46], [47].

Forecasting

The model is used to produce the final prediction after finding the best model's conversion, differencing, and ARMA term applying either information criteria or MSE.

Forecast Averaging

Rather than selecting the optimal ARIMA model and forecasting from it, another approach is to forecast from each ARIMA model under consideration independently and then average over those forecasts to create a final prediction. EViews supports two methods of prediction averaging when doing automated ARIMA forecasting: Smoothed Akaike Information Criterion (SAIC) and Bayesian Model Averaging (BMA).[48] [49].

Results

The datasets ranged from 5/02/2017 to 6/25/2018, providing 290 surgical volume data. The median surgical volume was approximately 62, with standard deviation of 14.9. the minimum and the maximum surgical volume were 40, and 90 cases, respectively.

Figure 1 shows the forecasted and actual surgical volume of the collected data. The yellow line represents the forecasted surgical volume, the pink line indicates the actual surgical volume. The forecast comparison in figure 1 shows the prediction comparison of all the possible combinations of ARIMA model. Most importantly, the the average of all ARIMA models is shown.

Figures 2 demonstrates the performances of the different ARIMA models. It can be seen from the figure that the ARIMA models with lower AR and MA terms performed well in terms of loglikelihood, Akaike's Information Criteria, Bayesian Information Criteria, and Hannan-Quinn Information Criterion. We highlighted the top 20 best performing models with associated Bayesian Information Criteria in figure 3. The results showed that the ARIMA model with no AR and MA terms was the best performing model in our case.

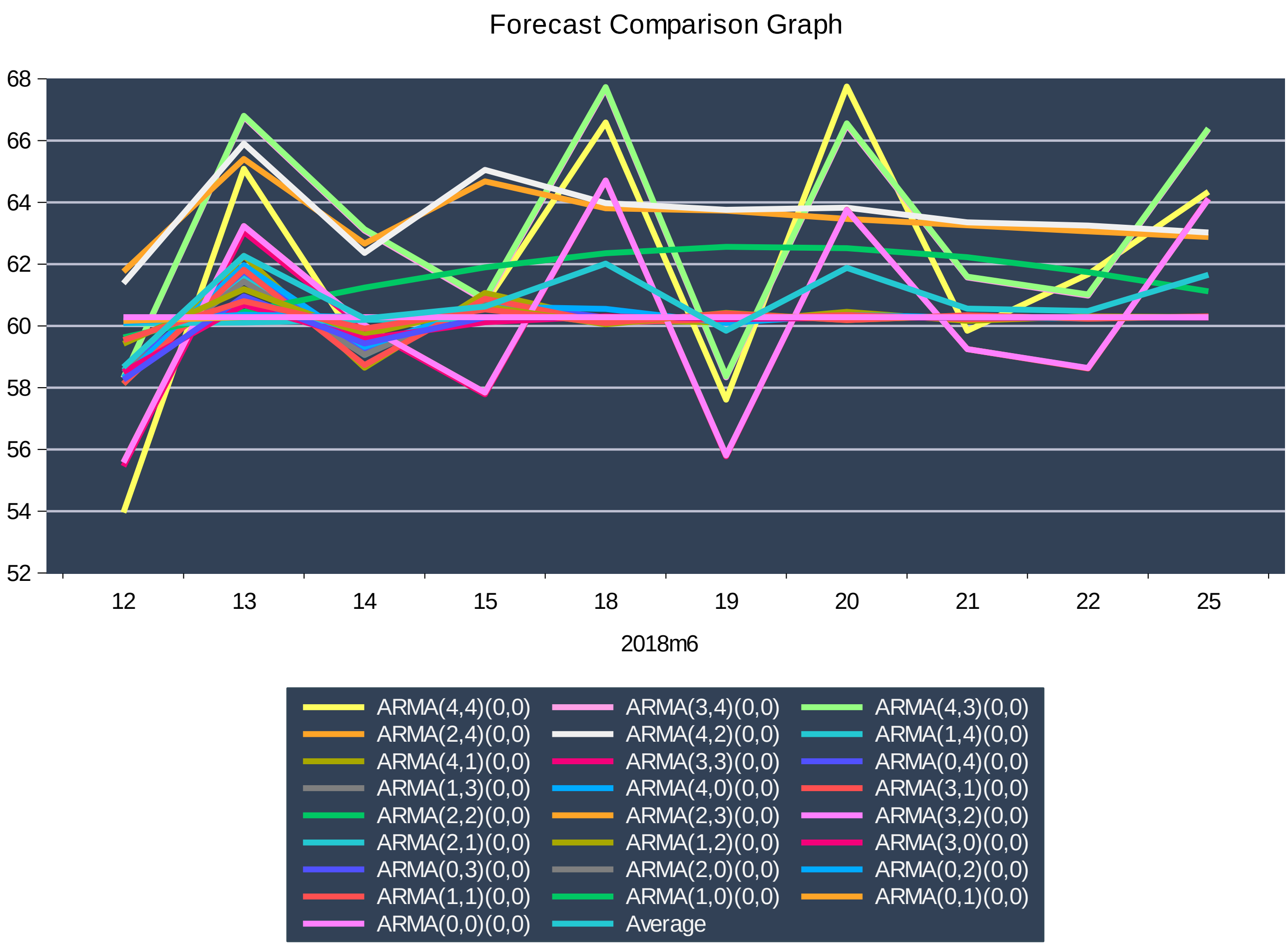

Figure 1. Forecast comparison and Averaging

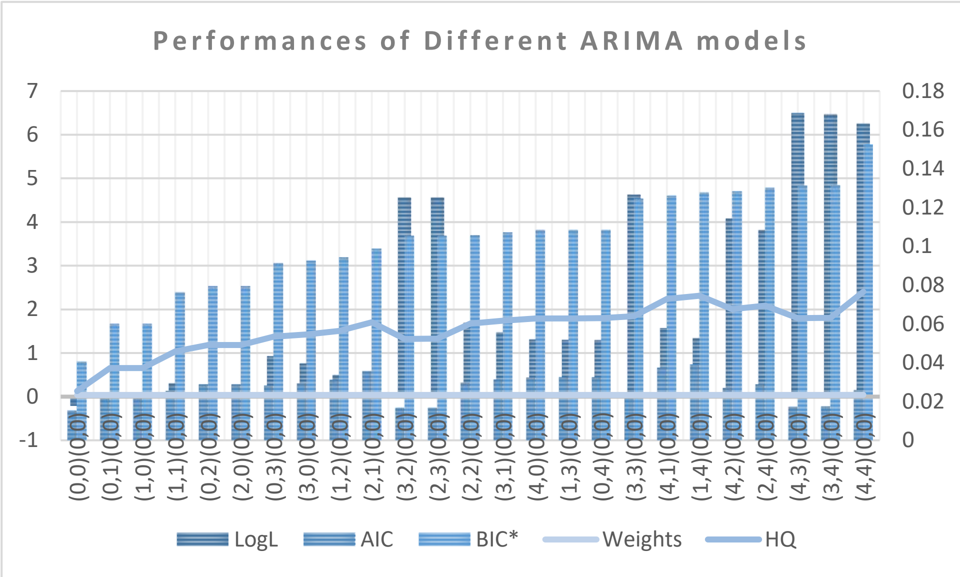

Figure 2. ARIMA model selection criteria

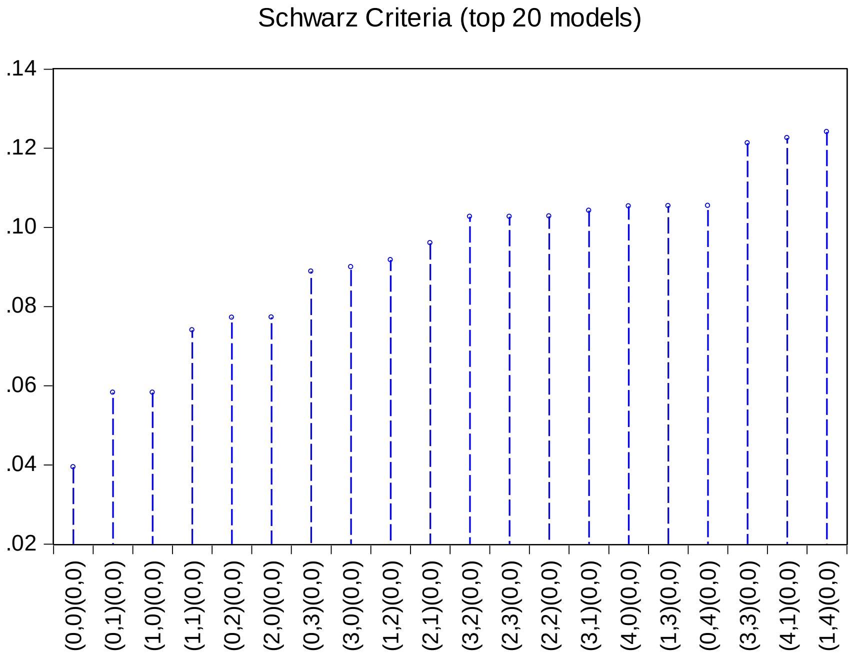

Figure 3. Top 20 models selected by SC

Conclusion

In the majority of hospitals, the operating room serves as both a significant revenue and expense center. As a result, improved management and scheduling practices in the operating room have the potential to provide considerable advantages. Not only does effective administration of an operating room need capable leadership, but it also requires a faultless organizational structure and the coordination of efforts across several disciplines. The procedure includes making decisions on the allocation of resources, providing guidance for roles and tasks, and often assessing performance. Hospital's employee satisfaction may be improved by the use of predictive modelling that take staff preferences into consideration. This can also reduce the amount of work that hospitals managers need to do, which is a relief for those in management positions. One of the fundamental tasks in planning is forecasting. The plans' success is dependent on the validity of the predictions. Many plans in service sectors, such as hospitals, rely on forecasts, ranging from resource planning to aggregation planning, layout choices to daily schedules.

Forecasts might be regarded the important input in the policy making process about operating rooms, in which facts obtained can either promote or obstruct the organization's vitality. It is critical in healthcare to use the proper data. Because there are several forecasting methodologies, the hospital manager must carefully assess which methodology will give them with the greatest insight and the best assistance for effectively applying that insight. A precise demand estimate indicates how many staffs, doctors, and resources are required for each health clinic—important for ensuring the high availability of key health items while ensuring a smooth distribution channel. Demand forecasting allows you to order the proper quantity of stock—underestimating demand leads to stockouts, while overestimating demand leads to expired/wasted items.

Accurate surgical volume forecasting is difficult because there are many variables which influence any health service, including seasonal fluctuations, illness outbreaks, demographic and migrating populations, provider prescription preferences, and the introduction of new goods. Simple intuitive approaches for anticipating demand do not account for all of the intricacies associated with seasonal items and user preferences. Using more advanced forecasting techniques often exceeds the intellectual boundary of human competence, particularly in resource-constrained clinics with employees and doctors that have conflicting needs for their time and focus. While adopting improved demand forecasting is an optimal beginning for using better analytics. Forecasts will frequently be biased or inaccurate. There will continue to be unexpected elements, no matter how complex the forecasting algorithms are.

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