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Use of Operations Research in the Healthcare Industry

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Abstract:

The world is moving forward with advances in the healthcare sector to increase the lifespan of people. Development of technological equipment in health care led to a steep increase in costs of each equipment, with this, hospitals have to focus more towards attaining the optimal utilization of resources in order to maximize profits and the number of patients attended. Operations Research contributes towards optimal, efficient and affordable techniques for the constituents in the health care industry. The following research paper studies four pertinent cases – Patient Services, Demand Forecasting, Patient Scheduling and Emergency Room Arrivals via Operations Research techniques like Goal Programming, Monte Carlo, Hybrid Tabu algorithm and Queuing Theory respectively. Goal Programming was performed on Microsoft Excel whereas other analysis done were referenced from previous research papers. Operations Research in healthcare is still raw where there is a lot of untapped potential, with hospitals slowly adapting measures to optimize the resources available to them but the difficulty of coalition of data makes it a task for hospitals to make advances.

Keywords **—Operations Research, Optimization, Healthcare Planning, Patient Scheduling, Staff Rostering, Forecasting.**

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I. INTRODUCTION

According to a study, around 4300 people in India die every day because proper care is not provided to them in hospitals, which can be in the form of an ambulance not arriving on time, operation theatres not being available during an emergency, lack of beds and medicines or even because of the hospital being short staffed on nurses and doctors (Ray, 2018).

Operation research is a discipline of applying appropriate analytical methods for decision making.

It has been used in health care since 1952.Operations research in the context of health care is research that yields knowledge that can be put to practical use (evidence, conclusions, information, and so on) that can help Implementation of the programme (e.g., effectiveness, efficiency, etc.) independent of the quality, access, scale-up, and sustainability.

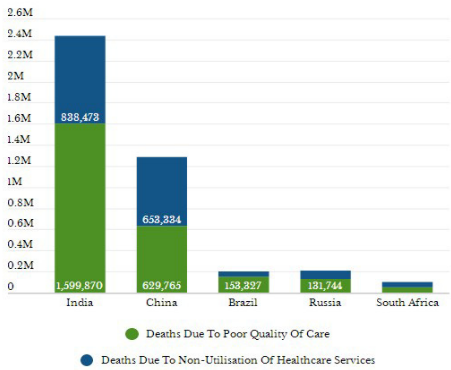

Figure1: Deaths Amenable to Healthcare in BRICS Countries

The sort of research (design, methodology, and approach) fits into this category. within the scope of operations research." In hospitals, the OR is being used a lot more. management, operations with limited resources, or treatment planning. The following are some of the most important aspects of healthcare optimization: Logistics, disease diagnosis, service planning, and medical care are all things that need to be considered. Preventive care, medicines, and resource scheduling. Using OR we can use techniques such as queuing theory and discrete event simulation to give various appointment strategies under different hospital or clinic settings.

Also, the reason for taking this topic is that there is overcrowding in emergency departments which is a worldwide problem and this affects the ability to give proper medical care within a reasonable period of time. The performance of ED in terms of patient flow can be given by using the queuing theory. Many research papers show that this theory can be used efficiently in health care. Samuel Fomundam and Jaffrey Herrmann in a research paper summarizes a range of queuing theory with results in the following areas: waiting time and utilization analysis, system design and appointment system.

Tools such as Goal Programming, Monte Carlo theory, Queuing theory and Patient Admission Scheduling Program (PASP) are used to make the industry more efficient.

Goal Programming, used for optimization of operation theatre scheduling.Monte Carlo Theory, helps in forecasting the number of incoming patients in the future.Queuing Theory, it is an important tool for managing patient flow in hospitals and emergency room arrivals.Patient Admission Scheduling Program, used to ensure that the patient is put under the correct department in order to get appropriate treatment.

These tools in turn help the institutions to take other important decisions such as the size of the emergency vehicle fleet in order to cover maximum geographic area, timely dispatching of ambulances and scheduling the shifts of nurses appropriately. The benefits of carrying out research on this topic will help the hospital staff to smoothly carry out the allotment of slots, operation theatres and ERs. This will also benefit the patients as their waiting time will reduce. The advantage to the hospital is that, due to efficient allotment, they will be able to increase the patient intake in a day.

II. LITERATURE REVIEW

Within the last 2 decades, the involvement of Operations Research (OR) in the Health Care Sector has risen at a steady growth rate. The natural resources available to mankind are finite, however, as opposed to this, the population consuming these resources is surging exponentially. Appropriate planning contributes towards an equitable distribution of resources to ensure a need-based allocation, as a result, Healthcare Planning constitutes a crucial part of OR in this sector. On the other hand, Healthcare Management facilitates the maintaining and functioning of a smooth and efficient workflow in various institutions across the healthcare sector.

Beginning with the planning process, the deployment of ambulances is one of the most critical services in the healthcare sector. This aspect needs to be fully functional as even a minor delay during any type of medical emergency can result in death or untreatable conditions. Hospitals must try to earn profits to stay afloat by keeping in control the ratio of vehicles per patient and setting a limit on the number of vehicles covering a specific number of patients. The author of this research paper, through an active demonstration of healthcare in Columbia, states how linear programming was used in order to find optimal solutions for the truck locations tagged along with simulations (Jain, Shah, Sadh, Marfatia, & Khandelwal, 2018). Similarly, another research paper took into consideration randomness and uncertainties into their convex optimization model to limit the number of emergency vehicles. However, they concluded that the model thus created was applicable only to cities where the population was either less than or equal to 1 million (Rais & Viana, 2010).

Another important factor in the healthcare industry is Demand Forecasting. Demand Forecasting means anticipating the demand for a particular medical or healthcare product and making the arrangements in advance to keep the situation normal. In demand forecasting, controllable and uncontrollable factors have to be taken into account. In 2004 Finarelli and Johnson developed a 9-step forecasting model for healthcare services (Finarella & Johnson, 2004). In healthcare, benefits can be given across the chain of supply if manufacturers can also improve the fulfillment rates and reduce their inventory costs at the same time. This can only be done by near accurate demand forecasting. Some technology companies are also developing a disease-based data model using the data available on population health. This model uses everyday data to predict the risk that an individual has of contracting an infectious disease (Altmann-Richer, 2018). A major drawback that usually arises with demand forecasts, is the tendency to be inaccurate, as they lack the raw data and with time, they tend to not cope up with the trends over long periods of time.

Allocating beds is an everyday task in hospitals and is dependent on factors such as total bed capacity, patient compatibility, fluctuations in lengths of occupancy and the rate of emergency arrivals. Generally, hospitals allocate beds based on a first come first serve. Higher occupancy rates also increase the probability of overflow situations which require a lot of additional work by the organization (Schäfer, Walther, & Hübner, 2018). A model used in the process of bed allocation is based on queuing theory and goal programming. The queuing theory is used to gather the important characteristics of the various departments in the hospitals. This data is then used to construct a multi-objective decision model taking into account the main goals related to consumer service and profitability (Li, Beullens, Jones, & Tamiz, 2009). In the queuing theory, first, the baseline criteria for each service are identified so that a particular load of patients can be handled based on the projected demand. A marginal analysis is then used to distribute the leftover beds to try and limit the overflow due to the fluctuations in demand (Kao & Tung, 1981).

The problem of bed allocation is based on the mathematical distributions and on the assumption that the client's behaviour is predicted and this cannot be guaranteed. Real-life situations are also often very complicated and can go beyond the philosophy of mathematics which again harms accuracy. Most of the institutions have multi-channel services and when one client is due for their service from the operator. They may end up not receiving the service and may then have to fall into a new queue after exiting the previous one. Lastly, this method is also very expensive and time-consuming.

Without management, the healthcare sector could fall apart into pieces as it requires continuous adaptation as it is ever-evolving with the drastic increase in number of patients. A queuing model provides the hospitals an efficient and smooth workflow partnered up with a cost-effective method. This research paper includes a case study on the Romanian Healthcare Industry wherein they use an M/M/3 queuing model for E.Ds. Here, different Triage Levels determine the waiting time for each medical patient, i.e., Level I signifies no waiting time whereas at Level V there is a maximum of 2 hours of waiting (Vass & Szabo, 2015). A technique like queuing reduces the chances of reneging and provides optimal waiting times for patients and helps in planning for emergencies beforehand (Fomundam & Herrmann, 2007).

Another perspective on scheduling in the healthcare sector, outside of the ED, is the basic practice of patients setting appointments with their respective doctors, based on their medical concerns. As a result, OR techniques are employed in this field also. These techniques are aimed at minimizing waiting times and cost and maximizing the optimal patient-staff setting. (Patrick & Puterman, 2008) set out the first model which helped patients scheduling via a Markov Decision Process. A Markov Decision Process is a mathematical framework that tends to present outcomes while having a balance between randomness and controllability (Jain, Shah, Sadh, Marfatia, & Khandelwal, 2018).

Nurse staffing is one of the most crucial aspects in a hospital setting since a significant portion of the budget of any hospital is allocated to nurses. They also add to the smooth and efficient functioning of hospitals. This actively demonstrates the reason why the healthcare sector invests time as well as money into OR to make optimal staffing schedules. In recent times genetic algorithms are the ones to go for in terms of creating schedules or timings where they can deal with multiple constraints at once.(Leksakul & Phetsawat, 2014) framed a model which helped obtain a certain level of staff cost while optimizing equality in terms of payments for overtime and maintaining higher levels of service provided. (Grano, Medeiros, & Eitel, 2009) upgraded the existing models by taking into consideration what the hospital requires in each moment as well as what the nurses would prefer in terms of working hours and times of the day. "Nurse-Patient Loyalty" is an issue that was solved by (Steeg & Schroder, 2007) using Constraint Programming combined with Linear Programming and metaheuristics. This helped reduce the number of nurses that visited a single patient (Rais & Viana, 2010).

While reviewing all the past research papers which mentioned the use of Operations Research in the healthcare industry, it was found out that there are areas in which OR has been very helpful. For example, in order to reduce the time for emergency services or optimal resource allocation. But OR has just started to pick up in the healthcare sector which means there are still many untapped areas that can improve the efficiency and lower costs for healthcare service providers as well as the ones receiving it.

The research objective for this paper is to evaluate the applications of Operations Research in the Health Care Sector through a critical analysis of various tools and models synonymous to bed allocation and patient services & demand forecasting via emergency services.

III. ANALYSIS & FINDINGS

A. Patient Service

This paper helps demonstrate the allocation of patient services via the usage of Goal Programming. Goal Programming is a technique and a variation of Linear Programming. It is a method which is used to solve a multi-objective optimization problem which consists of contradicting objectives. This research paper does exactly that and weights the objective to give one more importance than the other.

The data for this paper looks at hospitals across the city of Mumbai and has listed down the 4 most specialized types of surgeries performed alongside with the resources used to perform them. The 4 specialized surgeries are Cardiovascular and Thoracic Surgery, General Surgery, Plastic Surgery and Urology Surgery. The resources on the other hand are operating Room, General Room and the ICU *(K & A, 2015).*

Where Y1 = Number of Urology Surgery patients.
Y2= Number of Cardiovascular and Thoracic Surgery patients.
Y3 = Number of General Surgery patients
Y4 = Number of Plastic Surgery patients.

I1 = Idle hours of Operation Room.
I2 = Idle hours for General Room.
I3 = Ideal hours of ICU

Goal Programming Model:
Objective Function
Minimize total underachievement of goals = 5(dt-) + (dy1-) + (dy2-) + (dy3-) + (dy4-)

Subject to constraints
12500(Y1) + 4000(Y2) + 3000(Y3) + 1400(Y4) + dT- + dT+ = 300000 (Profit Goal)
12500(Y1) + dY1- + dY1+ = 50000 (Urology Patients Goal)
4000(Y2) + dY2- + dY2+ = 700000 (Cardiovascular and Thoracic Patients Goal)
3000(Y3) + dY3- + dY3+ = 800000 (General Surgery Patients Goal)

Table 2: Goal Programming Model

The values for the Yi's and di's were procured in Microsoft Excel with the use of the solver add-in, shown in Table 1.2. Excel Solver helped us decipher the following results:

Y1= 109.93, Y2= 175, Y3= 208.59, Y4= 214.29;

	Different Surgical Patients						
	Y1	Y2	Y3	Y4	Y5	Y6	Capacity
Operating Room (I1)	2	4	6	2	0	5	2300
General Room (I2)	5	6	6	5	5	10	3900
ICU (I3)	0	0	1	5	1	2	4000
Average Profit	1.25	4	3	2.25	1.4	2.1	lakhs

Table2: Deaths Amenable to Healthcare in BRICS Countries

1400(Y$) + dY4- + dY4+ = 300000 (Plastic Surgery Patients Goal)
2(Y1) + 4(Y2) + 6(Y3) + 2(Y4) <= 2600 (Operation Room Usage)
5(Y1) + 0(Y2) + 6(Y3) + 3(Y4) <= 3900 (General Room Usage)
0(Y1) + 6(Y2) + 1(Y3) + 5(Y4) <= 4000 (ICU Usage)

Y1, Y2, Y3, Y4, dY1-, dY1+, dY2-, dY2+, dY3-, dY3+, dY4-, dY4+ >= 0

The objective function aims to minimize the underachievement of the deviations to reach the target profit goals. The overall Profit Goal is given the utmost importance, hence a weightage of 5 is assigned to that target in comparison of 1 to the other profit goals. The constraints set are for the resources, where a capacity of 2600, 3900 and 4000 is for I1, I2 and I3 respectively.

dT- = dT+ = 0; dY1- = 0; dY1+ = 8742236;
dY2- = dY2+ = 0; dY3- = 1742236; dY3+ = 0;
dY4- = dY4+ = 0;

The Yi's values computed here gives the hospitals an idea to plan resources for the future in accordance with the constraints and goals set. For the following problem set, the total profit goal was achieved along with the Y1 and Y4. There was underachievement on part of Y3 and overachievement for Y2. Even though there wasn't an optimized solution, the model gives hospitals a foundation to follow when planning for patients' services.

The Operation Room capacity has been filled whereas the others have been left underutilised, hospitals could allocate more resources towards the operation room as it is significantly less than the other two constraints. As

	Y1	Y2	Y3	Y4	dT-	dT+	dY1-	dY1+	dY2-	dY2+	dY3-	dY3+	dY4-	dY4+				
	Urology Surgery	Cardiovasc-ular and Thoracic Surgery	General Surgery	Plastic Surgery	Under Achieve Total profit	Over Achieve Total profit	Under Achieve Y1	Over Achieve Y1	Under Achieve Y2	Over Achieve Y2	Under Achieve Y3	Over Achieve Y3	Under Achieve Y4	Over Achieve Y4				
Solution Value	109.9379	175	208.5921	214.2857	0	0	0	8742236	0	0	1742236	0	0	0				
Goal Weights					5		1		1		1		1		1742236.025			
Constraints :																	**Target to Meet**	**Achieved Goals**
Avg Profit Goal	125000	40000	30000	14000	1	-1									30000000	=	30000000	30000000
Y1 Goal	125000						1	-1							5000000	=	5000000	13742236.02
Y2 Goal		40000							1	-1					7000000	=	7000000	7000000
Y3 Goal			30000								1	-1			8000000	=	8000000	6257763.975
Y4 Goal				14000									1	-1	3000000	=	3000000	3000000
Operation Room	2	4	6	2											2600	<=	2600	
General Bed	5	0	6	3											2444.099379	<=	3900	
ICU	0	6	1	5											2330.020704	<=	4000	

the allocation is then shifted towards Operations room, comparatively it would free up some capacity there to account for emergencies and blockages and cater towards planning efficiently.

B. *Demand Forecasting*

The Monte Carlo model is an important tool used to forecast demand of patients coming into the hospital. This model falls under the stochastic model which describes various scenarios due to random variables. This model is usable among all hospitals, flexible and simple to construct. The results derived from these models can also be used for funding purposes.

The research will create a model to forecast the demand of patients and will ultimately result in the reduction in the waiting time and the time taken to give service to patients.

A simple multi queuing model is to be used, which is M/M/∞**.** If the arrival time fits Poisson distribution and service time to compliment the exponential distribution*(Yard.Doç Dr.Selim Tüzüntürk, 2015).*

Poisson Distribution:

$$=P(x;\lambda)\, e^{-\lambda}\lambda^{x} / x! \qquad \text{For } x=0,1,2,$$

Exponential Distribution:

$$= f(x)= \int_{0}^{x} 1/\beta e^{-t} / \beta \, dt$$

$$= 1- e^{-t/}\beta$$

$$\text{For } x \geq 0,\ t \geq 0$$

The Monte Carlo Model consists of five major steps. The very first step would begin with establishing the probability distributions for the given case. Followed by building a cumulative probability distribution for each and every variable provided as the second step. Next comes the setting up of random number intervals and generating random numbers as steps three and four. The final step consists of the simulation of the experiments and getting back the results in return.

In the simulation, the inputs are displayed by tools such as mean and standard deviation. When one or more inputs is described as a probability distribution, a number is randomly drawn and the output is calculated. This process is repeated thousands of times by the computer and each of these calculations is called an iteration. These iterations together approximate the probability of the final outcome.

The input distributions can be either continuous (for example, a normal distribution), or discrete (for example, a normal distribution), with probabilities connected to two or more unique scenarios (Stefan Thelin).

There are a few places which consist of the level of service, where care need should be taken into account. The second area which could see some improvement where the probability of successful intervention should be included. The final area of improvement could be the length of stay function should also be included.

The Monte Carlo Model in conclusion is an effective way to forecast the demand of incoming patients in any healthcare institution. It takes into account every possible outcome before giving a feasible solution and hence ensures that the inflow of patients can be handled efficiently and proper and timely care and treatment can be provided. As an added bonus, this also means that costs in healthcare institutions can be kept to a minimum by preventing wastage of resources and thus maximizing revenue.

C. *Patient Admission Scheduling Problem*

The factors that play a major role in this problem are: rooms, patients, timeslots and wards. Here are the following constraints. Patients, they very first one has even more subsets including gender, treatment requirement, age, duration of stay (admission and discharge dates) and finally room preference. Following patients, the second constraint is rooms, few basic elements related to rooms are- the ward they belong to, pre-existing equipment and the number of beds. Third being timeslots, the horizon of time must be continuous. Fourth is wards, it represents the range of treatments that can be conducted in the room. Finally, its over allocating,more than one patient cannot be allocated to one bed within the same time horizon.

The basic objective is to meet the all the needs of the patients while playing within the constraints of the problem. While solving this problem it is assumed that the admission date and discharge dates are already known. Lastly, it is also assumed that every patient will use at least one bed for some time (Berghe).

Demeester P, Souffriau W, De Causmaecker P, Berghe GV designed a hybrid tabu algorithm that automatically assigns beds to patients(Peter Demeester).

The solution is first patient is selected from the list of patients.After looking at the patient's medical requirements a list of all the departments that can fulfil those requirements is generated. The list is decided by the following parameters. The first departments are the ones who have the specialism as their major. The second departments are the ones who have the specialism as their minor.In the end we have departments that do not support the specialism at all. After the second step of looking at department requirements, the algorithm searches for a free timeslot in a department with the specialism as their minor, when there isn't a free room available. If the departments with the specialism as their minor are also completely occupied for the night, the algorithm will perform a search for a free timeslot in any other department. The four steps mentioned above are repeated till we run out of beds for the night, or till all the patients from the patient list are admitted.

This optimization method was tested by using a set of data that was randomly generated. Using this method in a real-life situation would have been more effective since it would reveal the method's effective while facing real life problems. Furthermore, this method needs a lot more investigation because this is a highly complex problem where we should consider other things such the Intensive Care Unit (ICU) and emergency admissions (Zahraa A. Abdalkareem).

Queuing theory investigates how lines form, function, and break down. The arrival process, the service process, and the number of individuals waiting to utilise a bed and an emergency are all investigated in queueing theory. Research papers show that this theory can be used efficiently in health care (Team, 2021).

D. *Emergency Room Arrivals*

Closures of EDs (Emergency Departments) and variation in ED patient arrival rates have led to increased crowding and prolonged waiting times that cause patient dissatisfactions leading to them seeking services at a different place. A lot of research and applications on queuing theory have been done in this area. A study examined the effectiveness of a queuing model in identifying staffing patterns to reduce the number of patients who leave without being seen and a conclusion was drawn that it can be very useful in most effective allocation of staff.The administration of medical care offices, for example, outpatient centres is extremely complex and demanding to manage. The objectives of this study on the clinics consists of the reduction of patient's time in the system, reduction of operation costs, better utilisation of resources and improvement on customer service. In depth analysis of the patient's arrival and flow, structure of the system, manpower characteristics and the scheduling system are included in the analysis. This theory is also used in hospital settings, which mainly include outpatient clinics and surgeries. Since the interns and assisting staff perform the small surgeries, they tend to arrive earlier than the experienced surgeons. Looking at this trend, the arrival patterns of patients or the service rate and time and appropriately scheduled surgeries can be determined for better efficiency.The Queuing Theory is also applied for Health care resources and infrastructure planning for disaster management. Any kind of catastrophe causes human and economic damage which demands an immediate response such as arrangement of medical services and rescue of individuals. This theory can be used as a simulation to answer the "what if" questions and be prepared for the disaster. For example, in a Bird Flu epidemic, the administrators used the model to give data regarding how many people were affected and the speed of the disease spread, etc (Mehandiratta, 2011).

The model for patient flow is as follows. Healthcare managers project workload for physical infrastructure and manpower planning and they must consider five typical measures to evaluate the service systems. These measures are average time and number of patients waiting, capacity utilization, probability that an arriving patient will have to wait for service and costs of a given level of capacity. Sometimes, it seems that healthcare managers seek 100% system utilization, but it is unrealistic so they should try to achieve a system that minimizes the waiting and capacity costs. They must ensure average arrival and services rate are constant to keep the system at a stable state. In an infinite population, patient arrivals are unrestricted, and can exceed the system's capacity at any given point. The capacity of each server and the number of servers being used determines the capacity of the queuing systems. Temporary overloaded systems are caused by highly variable arrival and service patterns because of which waiting lines occur. The emergency department in the hospital is a good example of the variability caused by the random arrival patterns. The arrives differs during the day and the service patterns varies because of different illness and conditions of patients and the time required to treat them. Queue discipline is the order in which customers are processed. The assumption of first-come, first-served basis to provide service is the most commonly encountered rule as the patients do not all represent the same risk so those with the highest risk and seriously ill, are treated first (Hajnal Vassa, 2015).

To estimate the number of providers needed, M/M/n queuing model can be considered. The service duration has an exponential distribution and the Arrivals occur according to a Poisson process which is a discrete distribution that shows the probability of arrivals in a given time period, where the mean and the variance are the same. Using this M/M/n model we assume that:

$$\frac{\lambda}{n\mu} < 1 \qquad (1)$$

In which:

n - number of servers

ρ- system utilization

1 / μ - service time

λ- arrival rate

μ- service rate

P_0 = probability of 0 units

P_k = -probability of k units

To optimize the process for the probability Pk the probability than an entering patient must queue for treatment which means that all physicians are busy. To calculate the probabilities these relations are used:

$$P_k = P_0\left(\frac{\lambda}{\mu}\right)^k \frac{1}{k!} \qquad k < n \qquad (2)$$

$$P_k = P_0\left(\frac{\lambda}{\mu}\right)^k \frac{1}{n!n^{k-n}} \qquad k >= n \qquad (3)$$

Based on the property that the overall sum of probabilities must verify:

$$\Sigma_{k=0}^{\infty} P_k = 1 \qquad (4)$$

Calculate P_0 and the probabilities P_i for any i. Until the number of arrivals k is less than the number of servers n, there is no queue. But if the number of arrivals exceeds the number of servers (then the process must be optimized to reduce the waiting time. This is the way in which queuing models are used to find out different data (Szabob, 2015).

IV. CONCLUSIONS

Whilst analysing the data, understanding pre-existing models and formulating conclusions we faced a lot of issues. Most of the models that we came across not only had an umpteen number of assumptions that would deem them infeasible in real life, but also did not take a lot of variables that could affect the results into account.

In this research paper we aimed to learn about and analyse the role of operations research in the healthcare industry. Upon reviewing the literature, analysing all the data and models we aimed to connect the dots back to our objectives.

We aimed to create a functioning model to perform and see how patient service demands are met in the health care sector. Furthermore, we looked at what would be the ideal set of resources allocated to each department in the hospital (ICU, Operation room, general room) to generate the maximum profit.

Apart from this we tried to forecast the demand of incoming patients in order to ensure that the healthcare institutions are adequately equipped to provide proper aid and care to the patients. This was achieved using the Monte Carlo theory which gives the most realistic solutions as it takes into account every possible variable and situation so that the institutions are ready to tackle even unforeseen situations

Lastly, we also wanted to optimize the process of patient admission scheduling. In order to achieve this, we analysed the solution to the "Patient Admission Scheduling Problem (PASP)" provided by a hybrid tabu algorithm that automatically assigns beds to patients. This solution was provided by Demeester P, Souffriau W, De Causmaecker P, Berghe GV.

V. LIMITATIONS & RECOMMENDATIONS

With its own set of limitations, Goal Programming, however efficient, still fails to take into account a multitude of variables. It does provide solutions albeit under a particular set of constraints, despite that, it isn't Pareto efficient. Not only is the user required to have prior knowledge in coding before accessing the model online, but the Goal Programming Model itself requires a specific software for its smooth functioning. In real-life, even if the hospital has been successful in meeting with a particular constraint, it cannot reject any patient that might walk-in at given point of time. However, Goal Programming falters in taking this into consideration thereby failing to analyse the patient service demand effectively. For future research topics, alternative analytical models should take into consideration more realistic scenarios and careful consideration as to new methods could be put into place to satisfy as well as be efficient for the health care sector to take into consideration.

Queueing models are an integral part of calculating and optimizing patient waiting times, but whilst in the calculation phase, averages were taken as every aspect is an approximation, consequently causing the results to be less effective. Queueing theory also assumes a steady state and that the arrival rate is state dependent, resulting in potential customers walking away if they see a long enough queue. Queuing models can be made more realistic by emulating emergency room behaviour when combined with other models like machine learning, simulation and optimization. This will filter different criteria like patient conditions and their requisite care.

The Monte Carlo simulation was researched for forecasting demand; it unveiled a few limitations at hand. The model in itself is extremely complex and difficult to interpret the combinations of interventions to use. The metric that is usually provided to calculated the capacity is unknown, making it harder to reach to conclusions to forecast demand correctly. The Monte Carlo simulation also requires a special software, which might be on the expensive side, where hospitals might not be keen on spending that amount of money for estimated figures. The rate at which patients walk into the hospital isn't normally distributed, where often the data is skewed to typical infection seasons like winter and monsoon. Future research could help tackle this. A suggestion might be to perform Monte Carlo on each category of patients making each one of them unique and can understand each patient type better.

A hybrid tabu algorithm was performed to reach an optimal patient admission scheduling problem. Now this algorithm runs on the assumption that each patient that walks in, has a fixed discharge date. Whereas in reality it's quite the opposite. Patients are often discharged late or early depending on the signs of recovery that they show, and as each patient is different, the discharge date is completely random. The second assumption that this model assumes is that there are beds available at all times, but uncertainties like the pandemic, can cause discrepancies to the functioning of the model. For future research, as this is a very raw and early stage for the model, it can later delve deeper into other parts such as the ICU and emergency admissions. Future model developments could include constraints such as bed blocking in order to account for the actual number of beds available to the patients.

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