OPTIMIZING AND IDENTIFYING OPERATIONAL CHALLENGES AND SOLUTIONS FOR OPERATION THEATRE

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Abstract:

This study focuses on optimizing and identifying operational challenges and solutions for operation theatres (OTs). The research investigates the key factors influencing the profitability of OTs, emphasizing the importance of better preoperative evaluations, patient optimization, and effective management of scheduling conflicts. The participants in the study highlight the significance of factors such as cleanliness, waste management, streamlined YOJNA approval processes, and maintaining the existing hospital system. Additionally, coordinating the availability of surgical instruments, regular meetings, and communication between the heads of anesthesia, surgical, and nursing departments emerged as crucial elements in maximizing profitability.

The findings underscore the role of strategic human resource planning, working during non-peak hours, coordinating surgical staff availability, and implementing regular training sessions for OT staff in optimizing human medical resources. The study concludes that these strategies contribute significantly to enhancing the overall efficiency of OT operations.

Furthermore, the research delves into the impact of infrastructure on OT performance. Participants acknowledge the positive influence of ceiling-mounted laminar flow, modular operation theatres, and an intelligent multi-agent planning (MAP) system in increasing operational efficiency. The study advocates for monitoring and optimizing equipment and instrument utilization in the OT, emphasizing the reduction of breakdowns through the incorporation of a differential pressure display unit with an inbuilt integral sensor. This approach is identified as instrumental in enhancing performance by ensuring the seamless functioning of equipment and instruments.

In conclusion, this research provides valuable insights into the operational challenges faced by OTs and proposes practical solutions to optimize their performance. The identified strategies encompass a holistic approach, addressing human resource management, infrastructure enhancement, and efficient equipment utilization. Implementing these solutions is crucial for not only maximizing profitability but also improving the overall quality and effectiveness of healthcare services provided in operation theatres.
Keywords: Operation theatre, optimization, profitability, , strategic human resource planning, non-peak hours, training sessions, intelligent multi-agent planning (MAP) system, healthcare efficiency.

1. INTRODUCTION

Over the past three to four years, healthcare organizations have encountered numerous challenges attributed to various factors, including the rise in the elderly population, the occurrence of the COVID-19 pandemic, and notable financial constraints. Consequently, this has heightened the pressure on healthcare sectors, particularly in terms of surgical costs. As a result, hospitals are consistently seeking ways to provide high-quality patient care at an economical cost.

Over the last decade, the operation theatre has become a significant sector within the healthcare system, primarily attributed to the increased rate of hospitalizations for surgical procedures. Furthermore, the operation theatre holds a pivotal role in influencing the profitability of a hospital's income, making it a subject of particular importance for healthcare institutions. Hospitals are actively exploring effective approaches, and administrators are eager to discover optimal methods for managing the operation theatre to enhance both efficiency and service quality.
Common Challenges in Operating Rooms Include:

i) Inefficient Workflow

ii) Insufficient Documentation and Record-Keeping
iii) Heightened Risk of Errors
iv) Deficient Integration and Communication Between Operating Rooms
v) Escalating Costs

2. MAIN OBJECTIVES

i) Ensuring timely execution of operations without prolonged waiting periods.
ii) Enhancing the efficiency of human medical resources.
iii) Attaining optimal profitability.

In the current scenario, there exist numerous challenges in managing the system while maintaining high-quality patient care. Efficient and effective utilization of human resources is imperative.

3. RESEARCH METHODOLOGY

The study falls under the Empirical category and was carried out in an urban area of Gujarat. It encompassed four distinct regions within Gujarat, namely North, South, East, and West. In Gujarat, we have selected cities that Ahmedabad, Amreli Banaskantha, Bhavnagar, Dang, Jamnagar, Junagadh, Kheda, Kachchh, Mehsana, Panchmahal, Rajkot, Sabarkantha, Surat, Surendranagar, and Vadodara.

3.1 Sampling Design

3.2 Population: Physicians from four regions within Gujarat
Sampling Frame: Physicians from the northern, southern, eastern, and western regions, selected from medical colleges and hospitals in Gujarat based on their geographical location.

3.3 Sample Technique: The random sampling method was employed.

3.4 Sample Size: Considering a population size ranging from 400 to 1000, with a confidence level of 95% and a margin of error set at 5.0%, the calculated sample size ranges from 196 to 278. A sample size between 197 and 278 is considered appropriate, and we opted for a total sample size of 200.

Required Sample Size†

Population Size	Confidence = 95%				Confidence = 99%			
	Margin of Error				Margin of Error			
	5.0%	3.5%	2.5%	1.0%	5.0%	3.5%	2.5%	1.0%
10	10	10	10	10	10	10	10	10
20	19	20	20	20	19	20	20	20
30	28	29	29	30	29	29	30	30
50	44	47	48	50	47	48	49	50
75	63	69	72	74	67	71	73	75
100	80	89	94	99	87	93	96	99
150	108	126	137	148	122	135	142	149
200	132	160	177	196	154	174	186	198
250	152	190	215	244	182	211	229	246
300	169	217	251	291	207	246	270	295
400	196	265	318	384	250	309	348	391
500	217	306	377	475	285	365	421	485
600	234	340	432	565	315	416	490	579
700	248	370	481	653	341	462	554	672
800	260	396	526	739	363	503	615	763
1,000	278	440	606	906	399	575	727	943
1,200	291	474	674	1067	427	636	827	1119
1,500	306	515	759	1297	460	712	959	1376
2,000	322	563	869	1655	498	808	1141	1785
2,500	333	597	952	1984	524	879	1288	2173
3,500	346	641	1068	2565	558	977	1510	2890
5,000	357	678	1176	3288	586	1066	1734	3842
7,500	365	710	1275	4211	610	1147	1960	5165
10,000	370	727	1332	4899	622	1193	2098	6239
25,000	378	760	1448	6939	646	1285	2399	9972
50,000	381	772	1491	8056	655	1318	2520	12455
75,000	382	776	1506	8514	658	1330	2563	13583
100,000	383	778	1513	8762	659	1336	2585	14227
250,000	384	782	1527	9248	662	1347	2626	15555
500,000	384	783	1532	9423	663	1350	2640	16055
1,000,000	384	783	1534	9512	663	1352	2647	16317
2,500,000	384	784	1536	9567	663	1353	2651	16478
10,000,000	384	784	1536	9594	663	1354	2653	16560
100,000,000	384	784	1537	9603	663	1354	2654	16584
300,000,000	384	784	1537	9603	663	1354	2654	16586

Fig. 1: Size of the Sample

3.5 Data Collection: Data collection was carried out through primary means. Primary data collection was conducted through a survey distributed via a Google link.

3.6 Questionnaire Design: The study employed a Likert scale comprising a numerical scale with multiple response categories. Categories of responses, spanning from strongly disagree strongly agree, typically consist of 5 options.

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Ranking	5	4	0	2	1

3.7 Survey Queries:

1. The profitability of hospital income is significantly influenced by the operation theatre.
2. Ceiling-mounted laminar flow is a crucial element in the composition of a modular operation theatre.
3. Strategic human resources planning helps in avoiding off-duty hours for planned surgeries.
4. Improved preoperative evaluation and patient optimization contribute to the enhanced utilization of the operation theatre.
5. Anesthetists, surgeons, and other staff members express willingness to work during non-peak hours.
6. Modular operation theatres contribute to better patient outcomes due to laminar flow.
7. Conflicts or overlaps in scheduling surgeries occur among different surgical specialties.
8. Cleanliness and waste management practices in the operation theatre contribute to its effectiveness and help prevent the rescheduling of surgeries.
9. Smoothing the YOJNA approval process enhances the utilization of the operation theatre.
10. The hospital faces challenges in coordinating the availability of skilled surgical staff during high-demand periods.
11. Hands-free telephone is not deemed an essential feature of the control panel of a modular operation theatre.
12. The intelligent multi-agent planning (MAP) system explores the automation of planning for operation theatre scheduling.
13. The hospital has a system in place to address conflicts or scheduling issues.
14. The hospital encounters challenges in coordinating the availability of required surgical instruments and equipment for scheduled surgeries.
15. The hospital implements measures to monitor and optimize the utilization of equipment and instruments in the operation theatre.
16. The differential pressure display unit with a built-in integral sensor is a crucial feature of a modular operation theatre.
17. Regular meetings and communication between heads of the anesthesia department, surgical department, and nursing department aid in coordinating and prioritizing surgical schedules.
18. Frequent breakdowns of medical equipment and facilities in the operation theatre impact operation theatre scheduling.
19. Regular training sessions for operation theatre staff contribute to improved patient care.

3.8 Coding:
A codebook was developed to facilitate the coding and deciphering the data for analysis.

3.9 Statistical Tools:
Diverse statistical methods were utilized for data analysis.

3.10 Reliability and Descriptive Analysis:
The Likert Scale employed in the study uses 5 to represent strongly agree, 4 for agree, 3 for neutral, 2 for disagree, and 1 for strongly disagree. The study aimed to comprehend the survey. One crucial statistical test used was Cronbach's alpha for measuring internal consistency reliability.

3.11 Measures of Relationship:
a) Co-variance: It is the average of the product of the deviations of two items from their mean, determining

how much two items vary together.
b) Correlation: It indicates the relationship between two variables, such as dependent and independent variables. Pearson's correlation coefficient is commonly used to indicate a linear relationship between two variables.

4. LITERATURE REVIEW

In a 2006 study conducted by Fei and Chu, an effective weekly operating program was developed through problem-solving utilizing a heuristic procedure based on a column generation technique. Subsequently, the daily scheduling problem for the operating theatre was addressed using a hybrid genetic algorithm. The output was obtained after verifying and testing the proposed problem with randomly generated data.

Al-Shifa Hospital, one of the largest hospitals in the Gaza Strip, boasts sixteen surgery rooms exclusively utilized for elective surgeries, encompassing both general and specialized procedures. The hospital performs 35 elective surgeries daily, with an average of 27 elective surgeries conducted regularly (Abdelall et al., 2020). Scheduling in the hospital follows a First Come First Served (FCFS) rule, where the first patient is allocated the first available time slot. Data analysis indicated that only 8% of elective surgeries were performed as per the schedule. The study aimed to schedule surgeries based on the priority of patients' health, as determined by criteria/sub-criteria, rather than relying solely on the FCFS basis. Criteria/sub-criteria included disease severity, difficulty in performing daily activities, hospital readmissions, patients with other diseases, and patient age. Analytic Hierarchy Process (AHP) was employed to rank each criterion/sub-criterion. AHP analysis highlighted disease severity and difficulty in performing daily activities as the most critical criteria, followed by hospital readmissions, patients with other diseases, and patient age, respectively. A model for each department based on the Linear Programming model (LP) was developed to maximize surgeries. Patients with high priority were scheduled ahead on FCFS, while those with surgeries last in the schedule were ranked lowest. The neurosurgery department received the highest priority.

Another study indicated that the required time for surgical interventions in operating rooms (OR) may significantly deviate from predicted values Depending on the nature of operations surgical team, and the patient (Najjarbashi, Lim 2020). These deviations hindered the proper optimization of OR resources and disrupted the estimated surgery start times. The study proposed a two-stage chance-constrained model for the OR scheduling problem under uncertainty, aiming to reduce costs associated with OR opening, overtime, and patient waiting times. The data experiments demonstrated that the proposed model achieved a better trade-off between minimizing costs and reducing solution variability compared to existing models in the literature. The study also established that individual chance constraints led to the opening of fewer rooms, lower waiting times, and shorter solution times compared to joint chance constraints. A decomposition algorithm, known to solve large instances of the NP-hard OR scheduling problem, was applied, with strong valid inequalities derived to accelerate convergence. The proposed approach outperformed both a commercial solver and a basic decomposition algorithm in solving all test instances, involving up to 89 surgeries and 20 ORs, in less than 48 minutes.

Another paper focused on the weekly operation scheduling problem of elective surgery based on the block scheduling policy, aiming to balance overtime and undertime of each surgeon's blocks (Luo, Bing, Wang 2019). The one-week operation problem involved allocating patients to blocks, achieving balance, and determining patients who could be scheduled the following week based on OR capacity, surgeon availability, and patient priority. Operation date, room, and sequence were also determined. Two Integer Programming (IP) models were presented to minimize the sum of all blocks' overtime and undertime penalty and to minimize the waiting cost for all patients. These indicators effectively balanced surgeons' workload and enhanced patient satisfaction. In contrast to previous studies, a fast method was introduced to calculate the number of blocks for each surgeon, reducing the problem scale. Computational experiments illustrated the applicability of the proposed method in the operating theatre.

The paper explored the surgical scheduling problem, considering surgical duration, setup time, turnover time, and due time. The actual surgical duration was influenced by factors such as normal duration, surgical sequence, accumulated experience of surgical teams, and a controlling parameter. Additionally, the setup time and turnover time were affected by a deteriorating effect, wherein postponing the start time, setup time, or turnover time of a surgery prolonged the actual duration, setup time, or turnover time. A schedule problem was formulated to minimize the maximum surgical tardiness. The surgical teams were required to operate surgeries in a non-decreasing order of patients' normal surgical duration. A branch-and-bound algorithm was provided to solve the surgical teams scheduling problem. Experimental results demonstrated the effectiveness and stability of the proposed algorithm (Abdeljaouad, Saadani, Bahroun, 2014).

This study introduces an optimization approach for emergency surgery operating room scheduling, emphasizing surgery priority. The goal is to minimize costs associated with elective and emergency surgeries while maximizing scheduled surgeries. The model also incorporates surgeon assistants for each surgery to achieve desired goals. Validated through a case study in an East Asian hospital using GAMS software, the proposed method employs hybrid simulation and the gray wolf optimization algorithm (GWO). Results indicate that increasing risk parameters in the robust optimization model raises system costs. In uncertain scenarios, solutions from the GWO simulation method outperform those from the GWO algorithm by an average of 73.75% (Rahimi, Gandomi, 2021).

In a different study, the authors address operating room scheduling considering uncertainty in operation times and the surgical team's composition. A combination of constraint programming and goal programming methods is used. The first stage assigns a balanced surgical team, while the second stage focuses on assigning operations to operating rooms. Evaluated based on operating room utilization rates and solution effectiveness, the model successfully generates efficient schedules (Gür et al., 2022).

The review you mentioned categorizes 246 technical articles on operating room scheduling from 2015 to 2020. It builds on previous classification schemes, identifying current trends and highlighting challenges in real-life implementations (Harris et al., 2022).

Another paper investigates the Adaptive Allocation Scheduling Problem with a modified block scheduling policy. It proposes a mixed-integer linear programming model with multiple objectives, efficiently solved using a column-generation-based heuristic algorithm and Benders' decomposition technique. Results show superior performance compared to existing methods (Kamran et al., 2020).

Addressing the operating room scheduling problem, one paper proposes a revised mathematical model to maximize room utilization and minimize costs. Four heuristics and local search procedures efficiently find feasible solutions, with a hybrid genetic algorithm (HGA) outperforming the proposed heuristics for large instances (Lin, Chou, 2019).

A study focuses on the Operating Rooms (ORs) Planning and Scheduling Problem with a modified block scheduling policy. A stochastic mixed-integer linear programming model is proposed, and a 2-phase heuristic solution approach outperforms the commercial solver CPLEX in terms of solution quality and CPU time for medium- and large-sized problems (Kamran et al., 2019).

Another paper addresses the challenges of manual operating room planning using a hybrid Bees Algorithm, specifically a Hybrid BA with Simulated Annealing. It efficiently solves the Master Surgery Scheduling Problem and Surgical Case Assignment Problem, considering both hospital and patient costs (Ibrahim Almaneea et al., 2019).

A comprehensive survey of operating room planning and scheduling problems classifies studied problems from various perspectives and identifies areas requiring further attention. The review underscores mathematical programming and heuristics as common approaches, highlighting future research trends (Zhu et al., 2018).

Another study tackles the Integrated Elective Surgery-Scheduling Problem (IESSP) in a privately operated healthcare facility. Two Mixed Integer Linear Programs (MILPs) model the IESSP as a three-stage hybrid flow-shop scheduling problem, demonstrating effectiveness on real-world and randomly generated instances (Hachicha et al., 2016).

Efficiently addressing the integrated operating room planning and scheduling problem, this paper combines surgery assignment to operating rooms and short-term scheduling. A branch-and-price-and-cut algorithm based on a constraint programming model is developed, showcasing superior efficiency compared to existing formulations (Hossein et al., 2016).

This chapter elucidates the intricate network connecting individuals through a shared system of encoding and decoding messages. The opening of the European gate has rendered intercultural communication ubiquitous, extending its reach to healthcare (Olmos, Casas, Rebull 2015). Tasks on an international scale necessitate culturally aware medical practitioners. The challenges, barriers, and solutions in this domain are expounded based on the authors' personal experiences. Despite personal insights, the chapter concludes that intercultural tension remains a major hindrance to patient healthcare services.

Hospitals often contend with underutilized and costly surgical units, underscoring the imperative for efficient operating room scheduling. Inaccuracies in scheduling can result in surgery delays or cancellations, posing Economic challenges for both individuals and healthcare institutions (Ozkarahan, Edis, Ozfirat 2015). Consequently, researchers in operations research and artificial intelligence have been dedicated to devising solutions for operating room scheduling and management problems since the 1960s. This chapter critically examines and deliberates various approaches and solutions proposed in the literature for operational-level operating room scheduling problems, intending to provide insights for researchers and offer efficient strategies for practitioners managing operating room schedules.

Hospital scheduling stands out as a complex challenge in the healthcare industry, prompting numerous global studies on both elective and non-elective surgeries. The consideration of various variables and factors, coupled with different methodologies and approaches, has been integral to scrutinizing hospital scheduling. As healthcare services and hospital operations continually evolve, there is an ongoing need for reviews and further studies. The significance of hospital scheduling becomes even more pronounced due to the persistent trade-off between limited resources and escalating demand, especially in volatile countries facing incidents like shootings and bombings. In such contexts, the disruption of hospital scheduling for elective surgeries by non-elective surgeries from war-related incidents is common. To address this issue, a paper proposes a hospital scheduling model centered on the neurosurgery department in Al-Shahid Ghazi Al-Hariri hospital in Baghdad, Iraq. The model seeks to maximize operating room utilization while minimizing surgery idle time, incorporating interruptions from non-elective surgeries into the main model using the Tabu search (TS) approach. Computational experiments demonstrate the model's feasibility and reasonable computation times. However, further testing is recommended as the problem size and computation times increase, suggesting the application of heuristic methods to enhance the practicality of the proposed model. Finally, the potential benefits of the study and the proposed model are discussed (Bouguerra, Sauvey, Sauer 2015).

The allocation and planning of operating rooms (ORs) represent crucial strategic decisions for OR managers. The number of ORs a hospital opens hinges on the allocation of blocks to surgical groups, services, or individual surgeons, along with the preferred availability for open postings (Hosseini, Taaffe 2015). An insufficient allocation of ORs may lead to unmet surgery demand, while an excess of ORs can be financially burdensome. Traditional methods for determining block frequency and size usually consider the average historical surgery demand for each group. However, accounting for demand variability is essential to ascertain the real OR requirements and avoid penalties for over- or under-utilized OR time. This paper introduces an algorithm that allocates block time based on demand variability, considering both over-utilized and under-utilized time within blocks. The algorithm is applicable when total caseload demand can be accommodated by the total OR resources without capacity constraints. It can modify existing blocks or allocate new blocks to surgeons without prior allocations. The study also explores the impact of turnover time on the required number of allocated ORs. Numerical experiments using real data from a large healthcare provider illustrate the potential for achieving significant OR time savings of over 2,900 hours through improved block allocations.

The challenge of the Operating Room Planning and Scheduling Problem lies in assigning surgeries to operating rooms and determining their schedules within a short-term planning horizon, considering constraints like surgeons' maximum daily working hours and surgery due dates. The problem is articulated within a column based on constraint programming generation framework. Computational outcomes demonstrate the effectiveness of the proposed algorithm, consistently yielding satisfactory solutions (Hossein, Doulabi, Rousseau 2014).

The Operating Theater (OT) constitutes a critical and costly hospital resource, with surgeries representing a substantial portion of hospitalizations. The primary objectives in OT management involve efficiently scheduling operations, minimizing waiting times, and optimizing resource utilization for maximum profitability (Guerriero, Guido 2011). Drawing parallels between management challenges in the OT and those encountered in manufacturing or transportation has driven the exploration of applicable models from industrial contexts. This paper introduces hybrid architectural concepts and a control system development to manage the entire operating room process, outlining the patient scheduling function and associated algorithm module based on distributed artificial intelligence.

The main objective of this paper is to devise a weekly surgery schedule for an operating theatre where time blocks are allocated to individual surgeons rather than specific specialties. Assuming multifunctionality of both operating rooms and recovery room spaces, the key objectives are to maximize operating room utilization, minimize overtime costs in the operating theatre, and reduce unforeseen periods of inactivity between surgical cases (Fei, Meskens, Chu 2010).

Addressing the weekly operating theatre planning and scheduling problem involves a two-phase approach. Initially, the planning problem determines surgery dates for each patient, considering the availability of operating rooms and surgeons. A set-partitioning integer-programming model is employed, solved using a column-generation-based heuristic (CGBH) procedure. This phase facilitates the allocation of surgery dates for patients. Subsequently, a daily scheduling problem is formulated to establish the sequence of operations in each operating room daily, considering the availability of recovery beds. Treated as a two-stage hybrid flow-shop problem, it is solved using a hybrid genetic algorithm (HGA). The schedules obtained from the planning phase guide scheduling decisions in this phase.

To assess the proposed method, obtained surgery schedules are compared with existing schedules from a Belgian university hospital, where time blocks are pre-assigned to specific surgeons or specialties months in advance. The results indicate that schedules generated by the proposed method exhibit reduced idle time occurring between surgical cases, significantly higher utilization of operating rooms, and lower instances of overtime. Overall, the findings underscore the effectiveness of the proposed approach in designing a weekly surgery schedule that optimizes resource utilization, minimizes overtime costs, and mitigates idle time between surgical cases, providing practical insights for hospitals and healthcare institutions aiming to enhance the efficiency and effectiveness of their operating theatre planning and scheduling processes.

The intricate task of scheduling elective surgeries within limited resources, encompassing surgical staff, nursing staff, anesthesiologists, medical equipment, and recovery beds, poses a complex challenge (Li, Xiangyong, Rafaliya, Navneetkumar, Baki, Md Chaouch, Ben 2015). A well-designed schedule should optimize resource allocation to ensure the overall system's efficiency and effectiveness. In this study, we propose an integer linear programming model addressing multiple goals to achieve an optimal schedule for elective surgeries, considering the availability of surgeons and operating rooms over a given time horizon. Specifically, our model focuses on minimizing key objectives, including the expected number of waiting patients for service, the underutilization of operating room time, the maximum expected number of patients in the recovery unit, and the expected range (difference between the maximum and minimum expected numbers) of patients in the recovery unit. To accomplish this, we develop two goal programming (GP) models: a lexicographic GP model and a weighted GP model, with the former prioritizing operating room scheduling based on different preemptive priority levels assigned to the four goals.

We perform a numerical analysis to illustrate the optimal master-surgery schedule derived from the proposed models. The results indicate that when the available number of surgeons and operating rooms is accurately known for the planning horizon, our models produce high-quality schedules. Moreover, the preference weights and priority levels assigned to the four goals significantly influence the resulting schedules. These findings offer valuable insights into the trade-offs that must be considered when adjusting the preemptive weights of the goals.

By utilizing a goal programming approach, our research contributes to the formulation of effective strategies for scheduling elective surgeries while considering multiple conflicting objectives. The outcomes of this study have practical implications for healthcare organizations seeking to optimize resource allocation and enhance overall system performance.

This paper delivers an extensive review of recent operational research conducted within the realm of planning and scheduling for operating rooms. We thoroughly examine literature across various domains relevant to either the problem context, such as performance measures or patient classifications, or the technical aspects, such as solution techniques or uncertainty management. Through diverse approaches in aggregating and evaluating papers, we provide a comprehensive and detailed overview, enabling readers to identify manuscripts aligned with their specific interests (Cardoen, Demeulemeester, Beliën 2010). In the course of this literature review, we summarize significant research trends in operating room planning and scheduling and emphasize aspects that warrant additional consideration in future research.

Hospitals, as essential service-oriented businesses, play a crucial role in improving the standard of patient care. In this pursuit, hospitals confront the challenging task of efficiently planning and scheduling operating room patients while considering budgetary, temporal, and staffing constraints (ICMLC 2022). Due to the intricate nature of scheduling problems, often classified as NP-hard, researchers have predominantly focused on developing heuristics and meta-heuristics rather than exact methods. Nevertheless, with ongoing advancements in high-performance computing, there is renewed interest in exploring precise techniques.

In this investigation, our main objectives to devise exact methods for addressing the operating room planning and scheduling problem. Our contribution involves creating an enhanced Integer Linear Program (ILP) using the Variable Neighborhood Search (VNS) meta-heuristic to optimize patient waiting times based on surgery priorities. Additionally, we introduce a novel lower bound derived from optimizing relaxed patient waiting times. Through experimentation, we validate the accelerated ILP's performance by comparing it with the original ILP. Furthermore, we demonstrate that the Lagrangian relaxation of the original ILP yields a high-quality lower bound.

5. ANALYSIS PART

Demographic Profile of the Participants
Sex Distribution: Upon analyzing the entire participant pool, it was observed that approximately 75% of the participants were female, while the remaining 25% were male, as displayed in Table 1.

Distribution by Gender		
Female	Male	Total
146	54	200

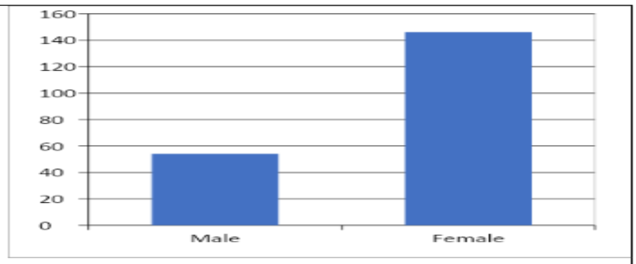

Table: 1 Gender wise Distribution

Chi-Square Test:
Analysis of Chi-Square Test (Question 4 versus Question 7)
H1: A significant association exists between the effectiveness of the existing hospital system in addressing conflicts or scheduling issues and the improvement in pre-operative evaluation and optimization of patients, impacting the optimization and profitability of hospitals in Gujarat.

The Chi-Square test indicates a P-value of 0.001, signifying statistical significance. Therefore, hypothesis H1 is supported, and the null hypothesis is disproven.

		Question 13									
		Agree		Strongly Agree		Disagree		Strongly Disagree		Total	P value
Q		Frequency	%	Frequency	%	Frequency	%	Frequency	%		
4	Agree	47	81.03	2	3.45	8	13.79	1	1.73	58	0.001
	Strongly Agree	69	49.64	32	23.02	35	25.18	3	2.16	139	
	Disagree	0	0.00	1	33.33	2	66.67	0	0.00	3	
7	Agree	74	67.89	10	9.17	24	22.02	1	0.92	109	<0.0001
	Strongly Agree	15	27.27	22	40.00	16	29.09	2	3.64	55	
	Disagree	26	76.47	2	5.88	5	14.71	1	2.94	34	
	Strongly Disagree	1	50.00	1	50.00	0	0.00	0	0.00	2	
8	Agree	72	67.29	6	5.61	26	24.30	3	2.80	107	<0.0001
	Strongly Agree	38	43.68	29	33.33	19	21.84	1	1.15	87	
	Disagree	6	100.00	0	0.00	0	0.00	0	0.00	6	
9	Agree	58	65.17	4	4.49	27	30.34	0	0.00	89	<0.0001
	Strongly Agree	48	48.00	31	31.00	18	18.00	3	3.00	100	
	Disagree	10	90.91	0	0.00	0	0.00	1	9.09	11	
17	Agree	40	70.18	1	1.75	15	26.32	1	1.75	57	0.012
	Strongly Agree	72	52.17	34	24.64	29	21.01	3	2.17	138	
	Disagree	4	80.00	0	0.00	1	20.00	0	0.00	5	

Table: 2 shows correlation between Question 13 versus Question 4, 7, 8, 9, 17

Chi-Square Test Analysis (Question 1 versus Question 7)
H1: A significant correlation exists between the effectiveness of the existing hospital system in addressing conflict or scheduling issues and the occurrence of conflicts or overlaps in scheduling surgeries among different surgical specialties, impacting the optimization and profitability of hospitals in Gujarat.
The Chi-Square test indicates a P-value of less than 0.0001, signifying statistical significance. Therefore, hypothesis H1 is supported, and the null hypothesis is rejected.

Chi-Square Test Analysis (Question 7 versus Question 8)
H1: A significant correlation exists between the effectiveness of the existing hospital system in addressing conflict or scheduling issues and the implementation of cleanliness and waste management practices in the operating theater, impacting the optimization and profitability of hospitals in Gujarat.

The Chi-Square test indicates a P-value of less than 0.0001, signifying statistical significance. Therefore, hypothesis H1 is supported, and the null hypothesis is rejected.

Chi-Square Test Analysis (Question 7 versus Question 9)
H1: A significant correlation exists between the effectiveness of the existing hospital system in addressing conflict or scheduling issues and the smoothening of the YOJNA approval process, impacting the optimization and profitability of hospitals in Gujarat.
The Chi-Square test indicates a P-value of less than 0.0001, signifying statistical significance. Therefore, hypothesis H1 is supported, and the null hypothesis is rejected.

Chi-Square Test Analysis (Question 1 versus Question 14)
H1: A significant correlation exists between the challenges faced by the hospital in coordinating the available surgical instruments and equipment for scheduling surgeries and the conflicts or overlaps in scheduling surgeries among different surgical specialties, impacting the optimization and profitability of hospitals in Gujarat.
The Chi-Square test indicates a P-value of less than 0.001, signifying statistical significance. Therefore, hypothesis H1 is supported, and the null hypothesis is rejected.

		Question 14									
		Agree		Strongly Agree		Disagree		Strongly Disagree		Total	P value
Q		Frequency	%	Frequency	%	Frequency	%	Frequency	%		
4	Agree	44	75.86	6	10.34	8	13.79	0	1.73	58	0.017
	Strongly Agree	67	48.20	45	32.37	24	17.27	3	2.16	139	
	Disagree	2	66.67	1	33.33	0	0.00	0	0.00	3	
7	Agree	70	64.22	17	15.60	22	20.18	0	0.00	109	<0.0001
	Strongly Agree	21	38.18	30	54.55	4	7.27	0	0.00	55	
	Disagree	21	61.76	5	14.71	5	14.71	3	8.82	34	
	Strongly Disagree	1	50.00	0	0.00	1	50.00	0	0.00	2	
8	Agree	77	71.96	8	7.48	21	19.63	1	0.93	107	<0.0001
	Strongly Agree	32	36.78	42	48.28	11	12.64	2	2.30	87	
	Disagree	4	66.67	2	33.33	0	0.00	0	0.00	6	
9	Agree	67	75.28	8	8.99	13	14.61	1	1.12	89	<0.0001
	Strongly Agree	40	40.00	43	43.00	15	15.00	2	2.00	100	
	Disagree	6	54.55	1	9.09	4	36.36	0	0.00	11	
17	Agree	44	77.19	6	10.53	7	12.28	0	0.00	57	0.001
	Strongly Agree	67	48.55	46	33.33	22	15.94	3	2.17	138	
	Disagree	2	40.00	0	0.00	3	60.00	0	0.00	5	

Table 3: shows correlation between Question 14 versus Question 4, 7, 8, 9, 17

Chi-Square Test Analysis (Question 4 versus Question 14)

H1: A significant relationship exists between the challenges faced by hospitals in coordinating available surgical instruments and equipment for scheduling surgeries and the implementation of cleanliness and waste management practices in the operating theater, impacting the optimization and profitability of hospitals in Gujarat.

The Chi-Square test indicates a P-value of less than 0.0001, signifying statistical significance. Therefore, hypothesis H1 is supported, and the null hypothesis is rejected.

Chi-Square Test Analysis (Question 9 versus Question 14)

H1: A significant relationship exists between the challenges faced by hospitals in coordinating available surgical instruments and equipment for scheduling surgeries and the smoothening of the YOJNA approval process, impacting the optimization and profitability of hospitals in Gujarat.

The Chi-Square test indicates a P-value of less than 0.0001, signifying statistical significance. Therefore, hypothesis H1 is supported, and the null hypothesis is rejected.

Chi-Square Test Analysis (Question 14 versus Question 17)

H1: A significant relationship exists between the challenges faced by hospitals in coordinating available surgical instruments and equipment for scheduling surgeries and the regular meetings and communication between Anesthesia, Surgical, and Nursing departments, impacting the optimization and profitability of hospitals in Gujarat.

The Chi-Square test indicates a P-value of equal to 0.001, signifying statistical significance. Therefore, hypothesis H1 is supported, and the null hypothesis is rejected.

Chi-Square Test Analysis (Question 1 versus Question 3)

H1: No significant relationship exists between strategic human resources planning and better pre-operative evaluation and optimization of patients, impacting the optimization and profitability of hospitals in Gujarat.

The Chi-Square test indicates a P-value of equal to 0.07, which is not significant. Therefore, hypothesis H1 is rejected, and the null hypothesis is accepted.

Chi-Square Test Analysis (Question 3 versus Question 7)

H1: A significant relationship exists between strategic human resources planning and conflicts or overlaps in scheduling surgeries among different surgical specialties, impacting the optimization and profitability of hospitals in Gujarat.

The Chi-Square test indicates a P-value of less than 0.001, signifying statistical significance. Therefore, hypothesis H1 is supported, and the null hypothesis is rejected.

Chi-Square Test Analysis (Question 3 versus Question 8)

H1: A significant relationship exists between strategic human resources planning and cleanliness and waste management practices in the operating theater, impacting the optimization and profitability of hospitals in Gujarat.

The Chi-Square test indicates a P-value of less than 0.0001, signifying statistical significance. Therefore, hypothesis H1 is supported, and the null hypothesis is rejected.

Chi-Square Test Analysis (Question 3 versus Question 9)

H1: A significant relationship exists between strategic human resources planning and the availability of equipment for scheduling surgeries and the smoothening of the YOJNA approval process, impacting the optimization and profitability of hospitals in Gujarat.

The Chi-Square test indicates a P-value of less than 0.0001, signifying statistical significance. Therefore, hypothesis H1 is supported, and the null hypothesis is rejected.

Chi-Square Test Analysis (Question 3 versus Question 17)

H1: A significant relationship exists between strategic human resources planning and the availability of equipment for scheduling surgeries and regular meetings and communication between Anesthesia, Surgical, and Nursing departments, impacting the optimization and profitability of hospitals in Gujarat.

The Chi-Square test indicates a P-value of equal to 0.0001, signifying statistical significance. Therefore, hypothesis H1 is supported, and the null hypothesis is rejected.

Similarly, other dependent and independent variables are mostly related, as the P-value is less than 0.05 in majority of analysis.

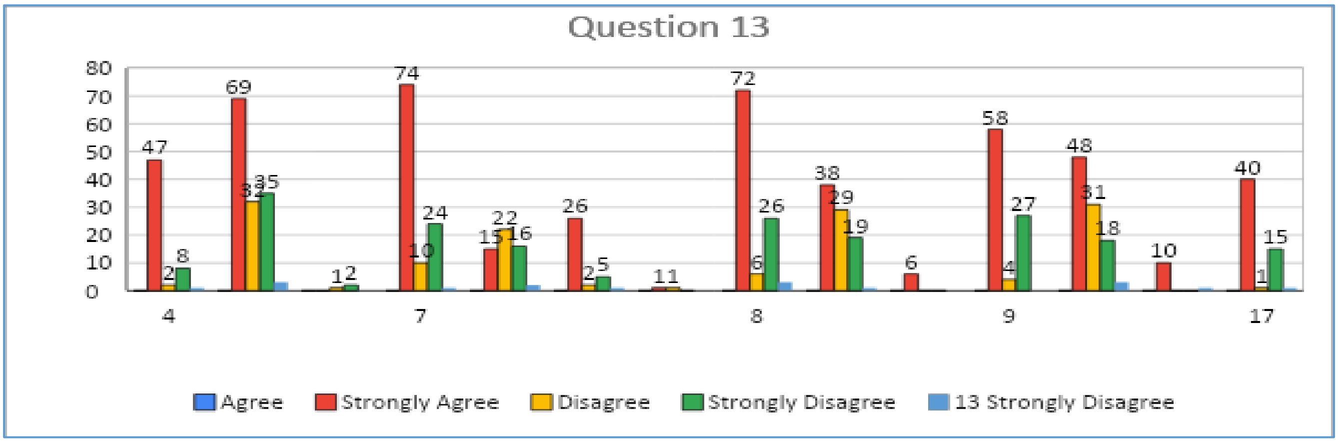

Figure 1: shows correlation between Question 13 versus Question 4, 7, 8, 9, 17
P value <0.0001

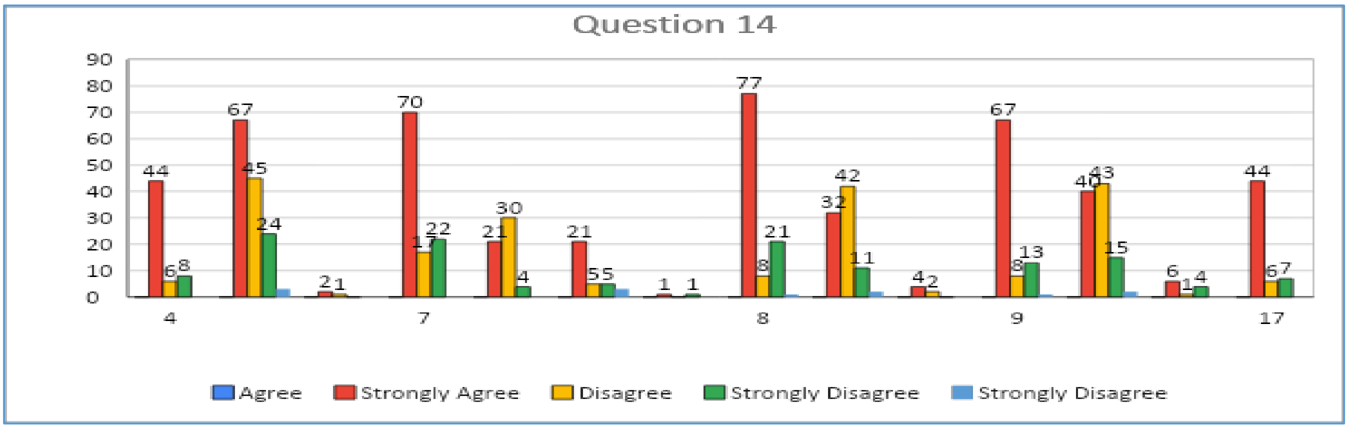

Figure 2: shows correlation between Question 13 versus Question 4, 7, 8, 9, 17
P value <0.0001

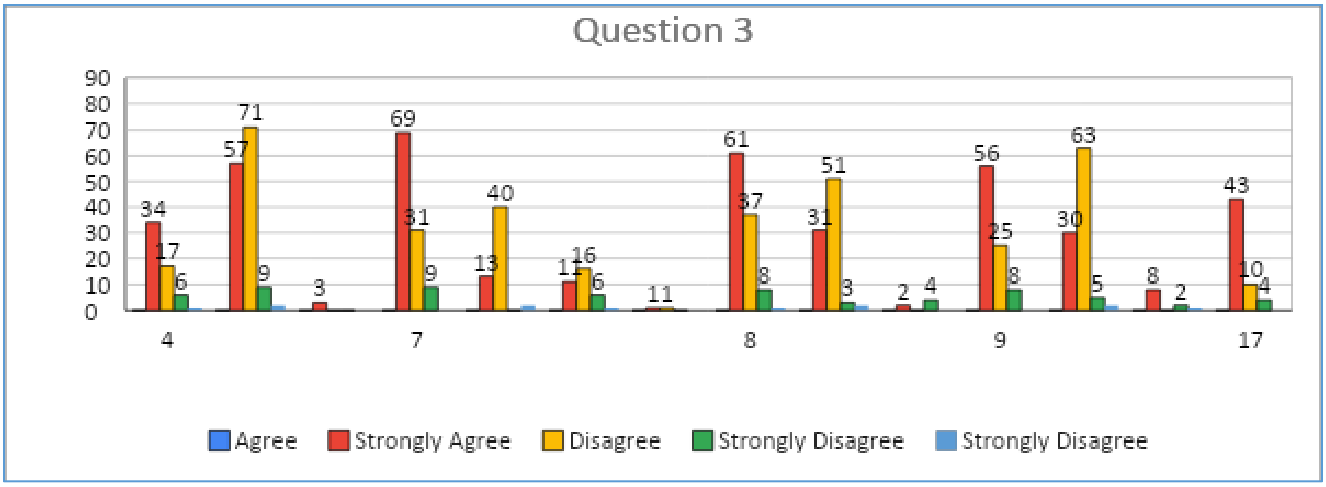

Figure 3: shows correlation between Question 3 versus Question 1, 7, 8, 9, 17
P value <0.0001

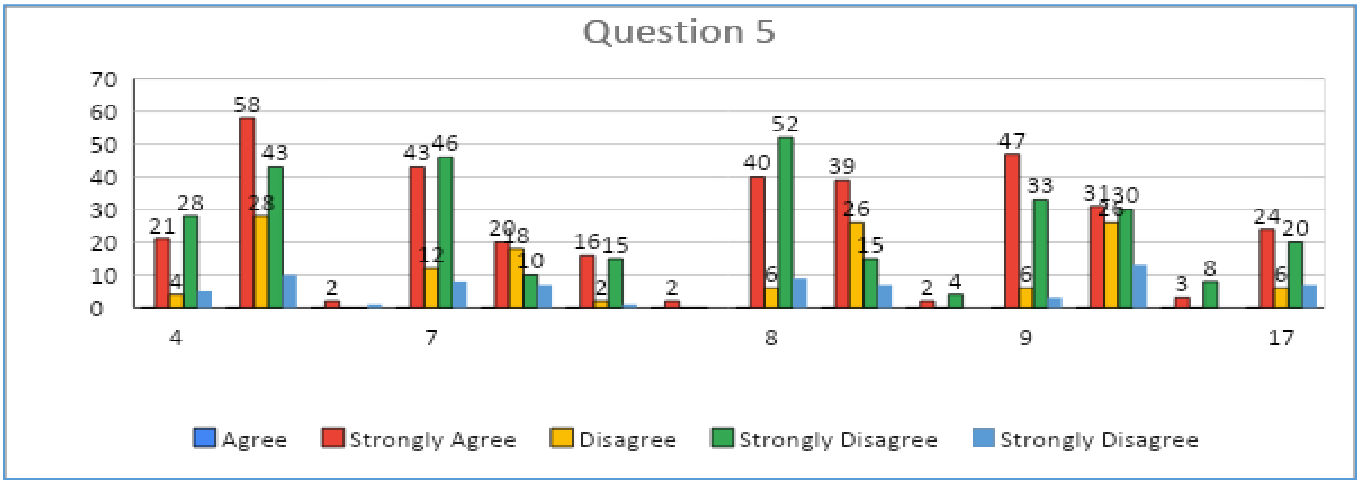

Figure 4: shows correlation between Question 5 versus Question 1, 4, 8, 9
P value <0.0001

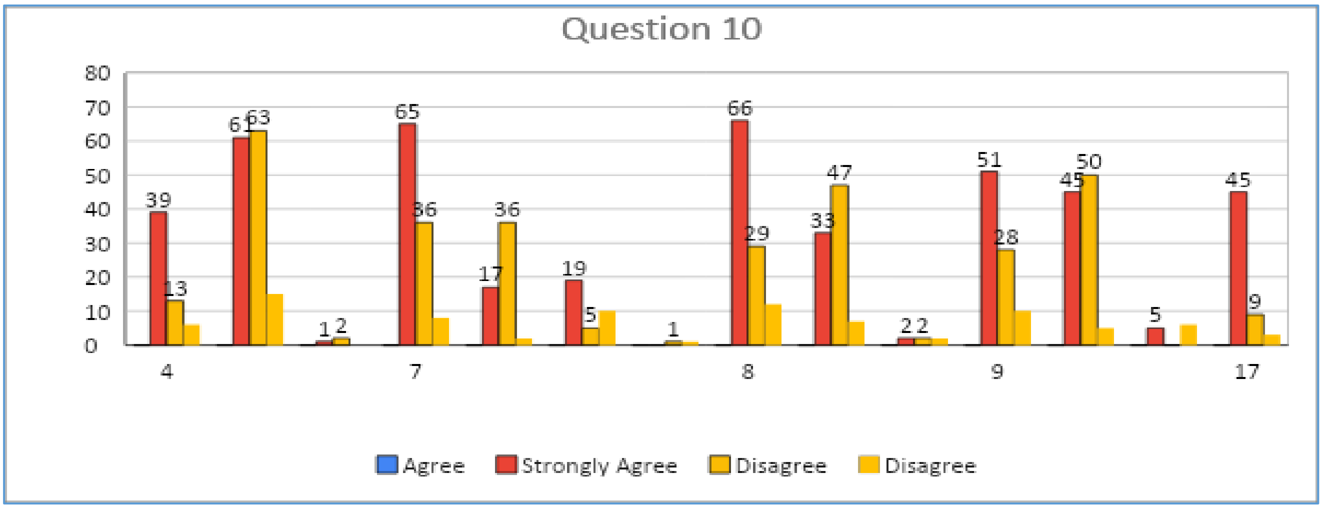

Figure 5: shows correlation between Question 10 versus Question 1,5,7,9
P value <0.0001

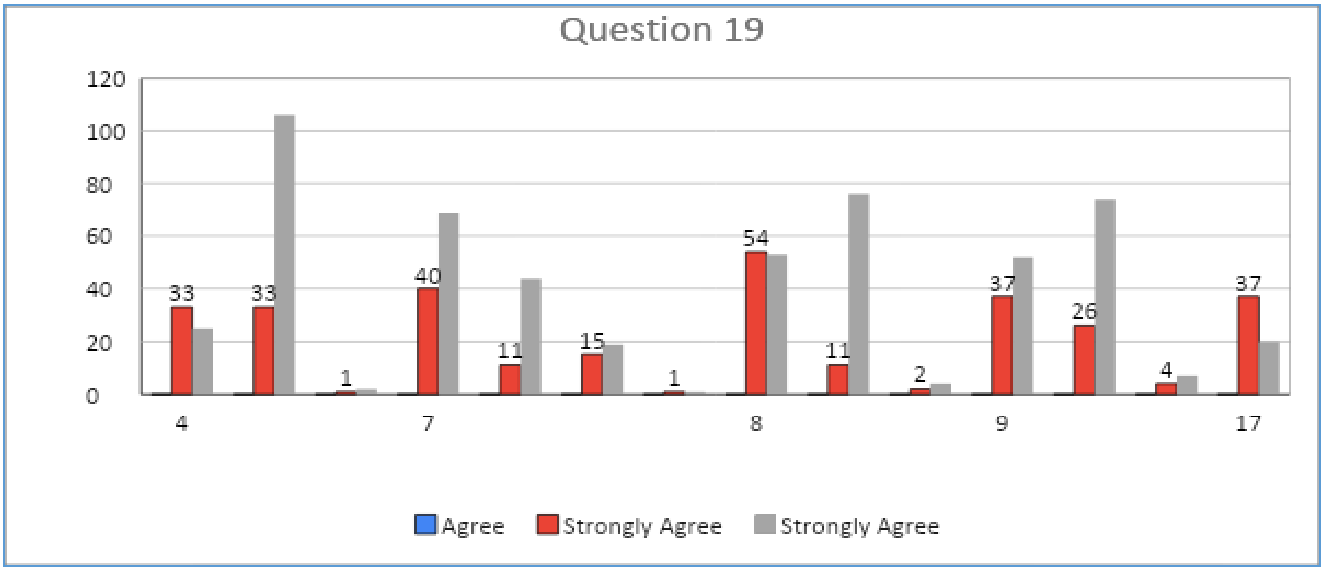

Figure 6: shows correlation between Question 19 versus Question 1,4,6,9
P value <0.0001

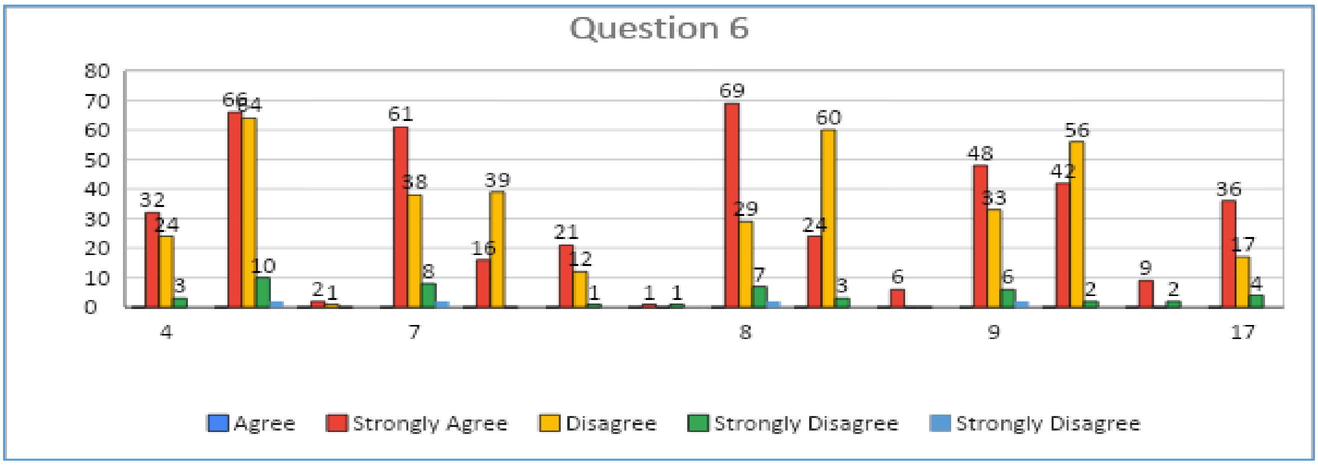

Figure 7: shows correlation between Question 6 versus Question 1, 4, 7, 9
P value <0.0001

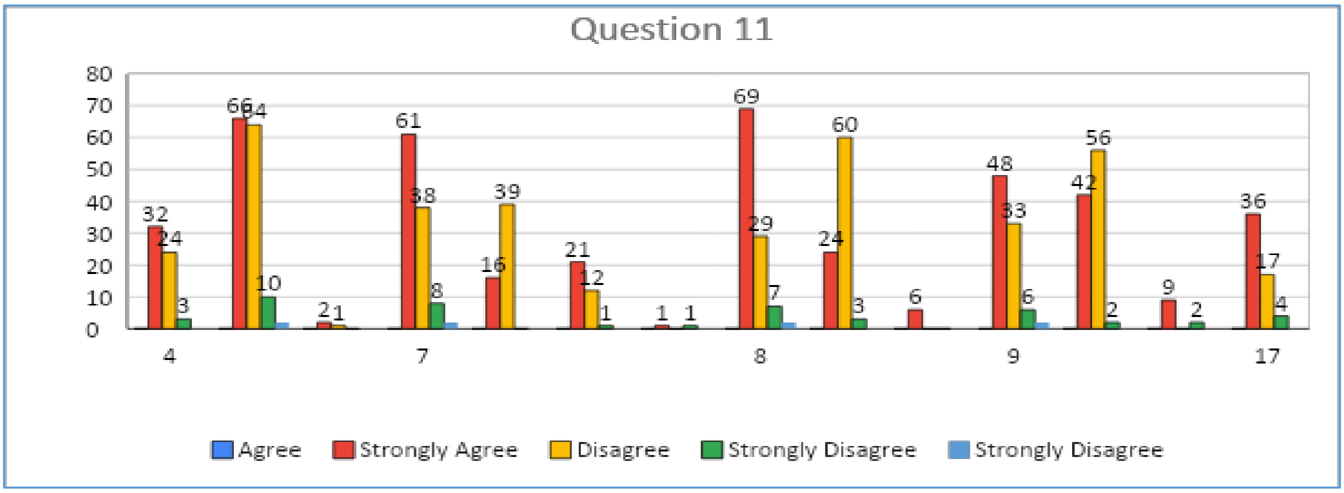

Figure 8: shows correlation between Question 6 versus Question 1, 4, 6, 9
P value <0.0001

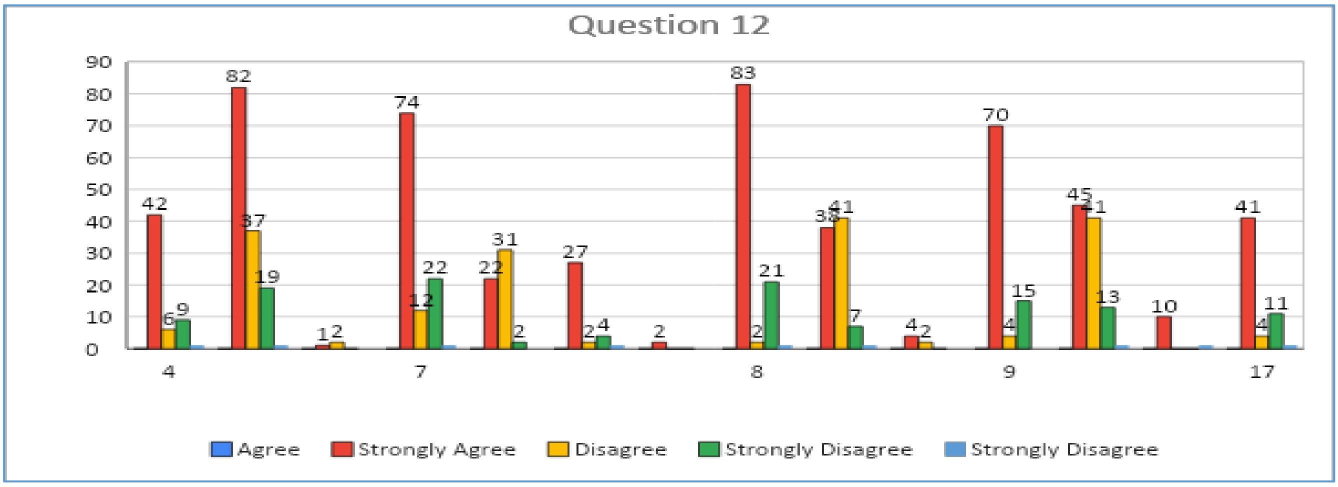

Figure 9: shows correlation between Question 6 versus Question 1, 4, 6, 10
P value <0.0001

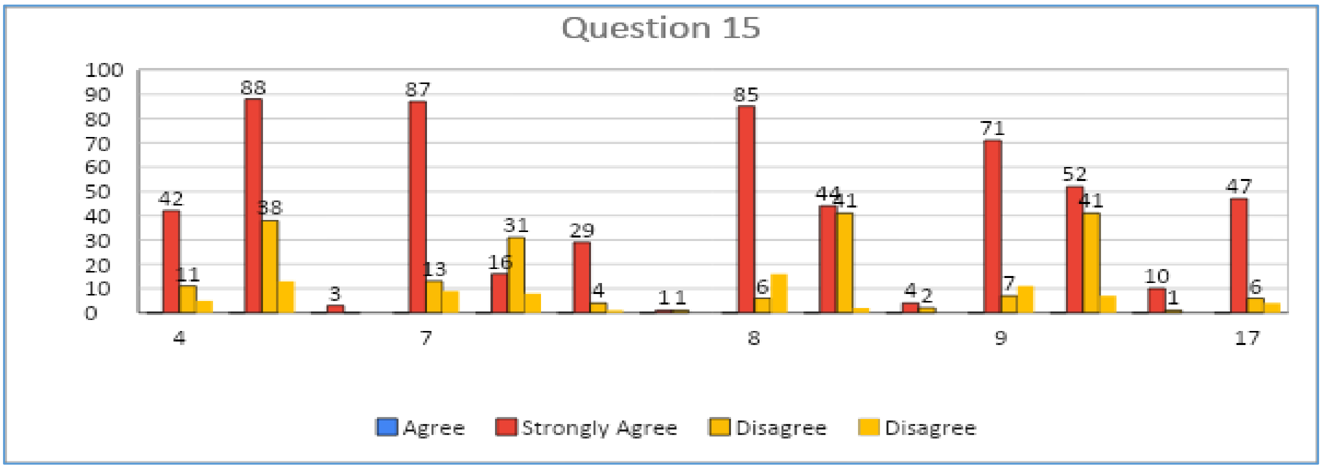

Figure 10: shows correlation between Question 6 versus Question 14, 4, 6, 11
P value <0.0001

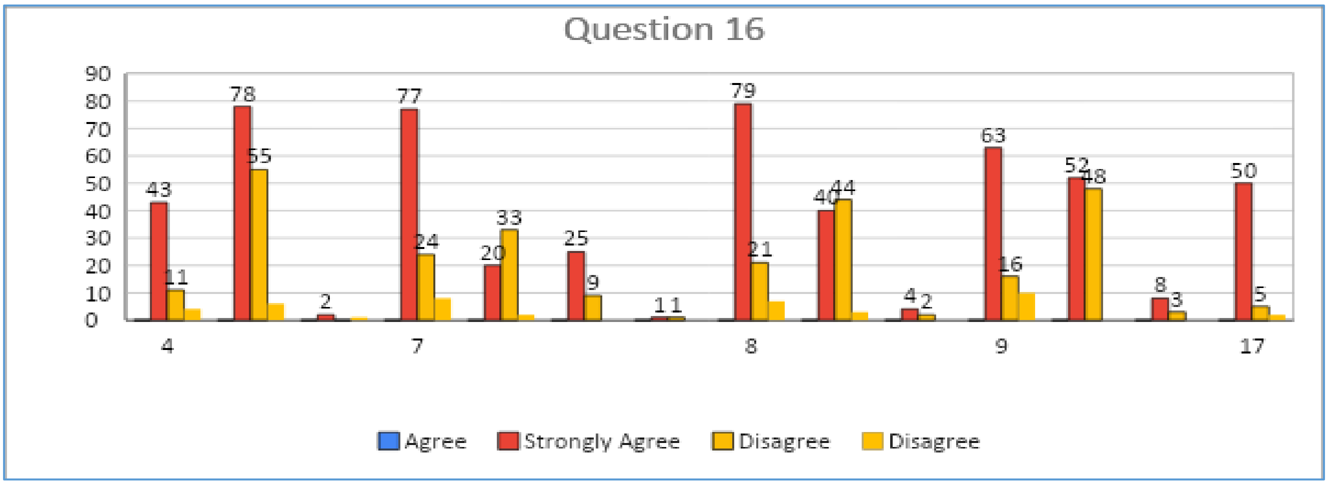

Figure 11: shows correlation between Question 6 versus Question 11, 4, 7, 10
P value <0.0001

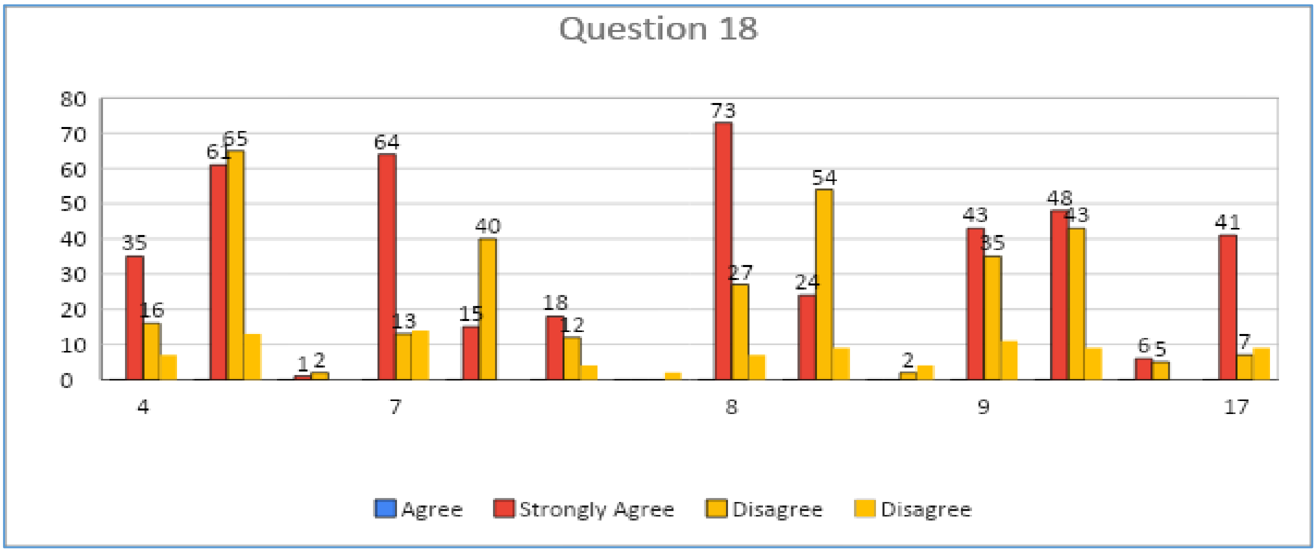

Figure 12: shows correlation between Question 6 versus Question 9, 4, 5, 10
P value <0.0001

6. FINDINGS

A study conducted by Fei and Chu in 2006 proposed the development of an efficient weekly operating program through problem-solving using a heuristic procedure based on a column generation procedure. The daily scheduling problem for operating theatres was addressed using a hybrid genetic algorithm. Al-Shifa Hospital, one of the largest facilities, houses sixteen surgery rooms exclusively utilized for elective surgeries, encompassing both general and specialized procedures. On a daily basis, the hospital performs 35 elective surgeries, with an average of 27 surgeries regularly (Abdelall et al., 2020). The scheduling follows a First Come First Served (FCFS) rule, and Analytic Hierarchy Process (AHP) was employed for criteria/sub-criteria ranking. Each department had a model developed based on a Linear Programming model (LP) to maximize surgeries.

In our investigation, precedence was afforded to patients with comorbid conditions. Research indicates that the required time for surgical interventions in operating rooms (OR) may significantly deviate from predicted values based on factors such as the type of operation, surgical team, and patient characteristics (Najjarbashi, Lim 2020). The proposed approach outperformed a commercial solver and a basic decomposition algorithm, demonstrating superiority after solving instances with up to 89 surgeries and 20 ORs in less than 48 minutes.

Our findings underscore the importance of reducing waiting time through optimal theatre utilization (Luo, Bing, Wang 2019). Two Integer Programming (IP) models were presented to minimize overtime and waiting costs, effectively balancing surgeons' workload and enhancing patient satisfaction.

The study's objective is to minimize costs associated with elective and emergency surgeries while maximizing scheduled surgeries, considering surgeon assistants for each surgery. The model utilizes GAMS software and employs a Hybrid simulation and the gray wolf optimization algorithm (GWO). Results show that increasing risk parameters in the robust optimization model leads to higher system costs. The GWO simulation method outperforms solutions from the GWO algorithm by an average of 73.75% (Rahimi, Gandomi, 2021).

The first paper mentioned is a review categorizing 246 technical articles on operating room scheduling published from 2015 to 2020 (Harris et al., 2022). Our study also emphasizes optimal utilization of human resources.

Authors, Kamran, Karimi, and Dellaert, developed a model combining a column-generation-based heuristic algorithm and Benders' decomposition technique. A genetic algorithm hybrid (HGA) was found to reduce wasting costs, increase operating room utilization, and lower overtime-operating costs (Lin, Chou, 2019).

Efficient OT management aims to schedule operations, minimize waiting times, Enhance and resource utilization for maximum efficiency (Guerriero, Guido 2011). Key objectives include maximizing operating room utilization, minimizing overtime costs, and reducing idle time between surgical cases (Fei, Meskens, Chu 2010).

Our contribution involves an enhanced Integer Linear Program (ILP) using Variable Neighborhood Search (VNS) to optimize patient waiting times based on surgery priorities. A novel lower bound derived from optimizing relaxed patient waiting times is presented, yielding a high-quality lower bound (ICMLC 2022).

7. CONCLUSION

The study reveals that profitability is primarily influenced by the operation theater, better preoperative evaluations, and conflict management in scheduling surgeries. Participants emphasize the significance of cleanliness, waste management, YOJNA approval smoothing, maintaining existing hospital systems, coordinating surgical instruments, and regular departmental meetings for maximizing profitability. The study concludes that optimizing human medical resources involves strategic human resource planning, working during non-peak hours, coordinating surgical staff, and conducting regular training sessions for OT staff. Enhanced OT performance is associated with better infrastructure, including ceiling-mounted laminar flow, modular operation theatres, and an intelligent multi-agent planning (MAP) system, along with monitoring and optimizing equipment utilization through pressure display units.

8. LIMITATION OF THE STUDY

The study was conducted in four regions of Gujarat due to limited resources and time. Perspectives of doctors from other hospitals may differ, especially in different geographical locations, institutions, and rural areas. The study did not cover villages, where lifestyles and education levels differ significantly, and potentially affecting perceptions.

9. SCOPE OF FUTURE STUDY

Future research can expand to include doctors from other regions and specialties globally. The developed tool for profitability and optimization assessment can be transformed into an application for universal hospital use. Further validation of the model in diverse geographical locations and with varied mindsets is warranted to enhance its applicability and relevance.

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