

**Midocean University**

**College of Business Administration**

MBA Program - Healthcare Management

**The Effect of Clinical Resource Optimization on Cost  
Efficiency  
in Intensive Care Units:**

**A Field Study in Saudi Public Hospitals**

*Secondary Analysis of Published Saudi Field Evidence*

Final Graduation Project Submitted in Partial Fulfillment of the Requirements  
for the Degree of Master of Business Administration

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جامعة ميدأوشن  
كلية إدارة الأعمال  
برنامج ماجستير إدارة الأعمال - إدارة الرعاية الصحية

أثر تحسين استخدام الموارد السريرية على كفاءة التكلفة  
في وحدات العناية المركزة  
دراسة ميدانية في المستشفيات الحكومية السعودية  
تحليل ثانوي لنتائج دراسات ميدانية سعودية منشورة

مشروع تخرج نهائي مقدم استكمالاً لمتطلبات الحصول على درجة  
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الفصل الدراسي الثاني

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## Arabic Abstract

### الملخص العربي

هدفت الدراسة إلى تحليل أثر تحسين استخدام الموارد السريرية على كفاءة التكلفة في وحدات العناية المركزة بالمستشفيات الحكومية السعودية. احتفظ البحث بعنوانه الأصلي، إلا أن جمع البيانات تم بطريقة التحليل الثانوي لنتائج دراسات ميدانية سعودية منشورة، وذلك بدلاً من استخدام الاستبانة أو الادعاء بجمع بيانات مباشرة من المستشفيات. شملت العينة ست دراسات كمية تناولت تحسين استخدام الأدوية، وممارسات العناية بالمرضى على أجهزة التنفس الصناعي، وكفاءة تشغيل المستشفيات ووحدات العناية المركزة.

أظهرت النتائج أن برنامج ترشيد المضادات الحيوية في عناية مركزة حكومية خفض الاستهلاك الكلي للمضادات بنسبة تقارب ٢٥٪، وخفض استخدام المضادات الوريدية بنسبة تقارب ٤٤٪. وعند استبعاد دواء لينيزوليد الذي أضيف حديثاً، انخفضت تكلفة المضادات من ٣٨'٧٢٣,٧٢ إلى ٢٥'٢٩٩,٢٤ ريالاً لكل ١٠٠ يوم سرير، مع وجود اختلاف بين قيمة الدلالة المذكورة في النص والجدول بالمصدر الأصلي. كما بينت دراسة أخرى أن ٤١,٦٪ من تدخلات الصيدلي السريري ارتبطت بتوفير محتمل في التكلفة، من دون حساب قيمة مالية نهائية.

وفي مجال الموارد التنفسية، ارتبط تطبيق حزمة الوقاية من الالتهاب الرئوي المصاحب للتنفس الصناعي بانخفاض معدل الإصابة بنحو ٤١,٦٪ وتوفير سنوي مقدر بلغ ١٥٤'٩٣٠ دولاراً. كما أدى مشروع وطني شمل ٤٢ وحدة عناية مركزة إلى تحسن شهري في ممارسات الفطام والرعاية اليومية وانخفاض شهري في الوفيات بنسبة ١٦٪، رغم عدم حدوث انخفاض في أحداث التنفس الصناعي أو مدة التهوية. وعلى المستوى التنظيمي، أظهرت بيانات ٩١ مستشفى حكومياً أن ٧٥,٨٪ منها كانت غير كفؤة فنياً، بينما ارتبط نموذج العناية المختلطة بانخفاض ذي دلالة إحصائية في نسبة إشغال الأسرة، مع تحسنات أخرى لم تصل إلى الدلالة الإحصائية.

خلصت الدراسة إلى أن تحسين استخدام الأدوية، وتطبيق حزم الرعاية التنفسية، والمراجعة والتغذية الراجعة، وتنظيم العمليات التشغيلية يمكن أن يدعم كفاءة التكلفة، لكن النتائج لا تمثل تحليلاً موحداً أو دليلاً سببياً قاطعاً بسبب اختلاف تصاميم الدراسات ومقاييسها. وتوصي الدراسة بتوحيد مؤشرات التكلفة لكل يوم مريض، وتوسيع خدمات الصيدلة السريرية، ومتابعة الالتزام بممارسات الفطام والوقاية، وإنشاء لوحات مؤشرات تشغيلية تربط التكلفة بالجودة والسلامة.

الكلمات المفتاحية: تحسين الموارد السريرية، كفاءة التكلفة، العناية المركزة، ترشيد المضادات الحيوية، التهوية الميكانيكية، المستشفيات الحكومية السعودية.

## English Abstract

This project examines whether using clinical resources more carefully can improve cost efficiency in intensive care units in Saudi public hospitals. The approved title remains unchanged, but the analysis is based on published Saudi field studies rather than a questionnaire or hospital data collected by the student. Six quantitative studies were selected. Together, they cover medication use, ventilator and respiratory care, and the organization of hospitals and ICUs.

The medication studies produced several practical findings. In one ICU, an antimicrobial stewardship program reduced total antimicrobial use by about 25% and intravenous use by about 44%. After linezolid, a newly introduced drug, was removed from the calculation, the reported cost fell from SAR 38,723.72 to SAR 25,299.24 per 100 bed-days. Because the article gives two different p-values for this result, the present project reports the size of the change but does not describe it as statistically significant. A second study found that 169 of 404 pharmacist interventions (41.6%) had the potential to save cost, although no final monetary value was calculated.

The respiratory-care evidence was also encouraging, although the results were mixed. A ventilator-care bundle was associated with a fall in ventilator-associated pneumonia from an estimated 3.39 to 1.98 cases per 1,000 ventilator-days, together with an estimated annual saving of USD 154,930. A national project involving 42 ICUs improved several daily ventilator-care practices, and mortality declined by 1.6% each month. Even so, ventilator-associated events, ventilation duration, and ICU length of stay did not improve. At the organizational level, 69 of 91 public hospitals were technically inefficient and the average efficiency score was 0.76. A separate ICU study reported a significant reduction in bed occupancy, while changes in several other indicators were not statistically significant.

Taken together, the evidence suggests that structured medication review, respiratory-care bundles, audit and feedback, and better operational planning can support more efficient resource use. The studies, however, used different designs and outcome measures. Their results should therefore be understood as a comparison of published evidence, not as a new national dataset or definite proof of cause and effect.

**Keywords:** clinical resource optimization, cost efficiency, intensive care, antimicrobial stewardship, mechanical ventilation, Saudi public hospitals.

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## Chapter One: Introduction

### 1.1 Introduction

An intensive care unit relies on many resources at once, including staff, medication, medical devices, laboratory testing, monitoring, and disposable supplies. This level of support is necessary because ICU patients can deteriorate quickly and may need immediate treatment. At the same time, small inefficiencies become expensive when they are repeated every day. Duplicate medication, avoidable device days, delayed treatment reduction, and weak coordination between teams are common examples.

Optimizing clinical resources is not the same as cutting care. The goal is to use a resource when it is needed, then review that need regularly. In an ICU, this may involve antimicrobial stewardship, pharmacist review, daily ventilator assessment, prevention bundles, audit and feedback, and better planning for beds and staff. Used properly, these approaches can reduce waste while protecting quality and patient safety.

Several Saudi studies have examined these issues in real hospitals. Haseeb et al. (2021) studied an antimicrobial stewardship program in an adult ICU in Makkah. Bukhari et al. (2012) studied a ventilator-care bundle in a public hospital ICU. Arabi et al. (2023) examined a national improvement project that included 42 ICUs in 26 hospitals. Other studies looked at pharmacist interventions, hospital technical efficiency, and changes in ICU operating models (Alatawi et al., 2020; Althomali et al., 2022; Alarifi et al., 2024).

Although these studies all come from Saudi healthcare settings, they do not measure the same outcomes. Some report direct costs, while others focus on medication use, safety, or operational performance. This project compares their findings around one main question: is improved management of clinical resources associated with better cost efficiency in Saudi public-hospital ICUs?

### 1.2 Problem Statement

Saudi public hospitals are under pressure to improve efficiency without weakening access, safety, or clinical outcomes. The issue is particularly important in intensive care, where equipment is expensive, medication use is high, and continuous staffing is essential. Existing Saudi evidence is divided across several topics. Medication studies examine antimicrobial use or pharmacist activities, respiratory studies focus on ventilator bundles and daily care, and management studies assess technical efficiency, occupancy, or ICU organization. Looking at each area separately makes the overall effect on ICU efficiency difficult to see.

The project was originally planned around new hospital data, but comparable clinical and financial records were not available to the student. Creating results, or presenting published figures as original data, would not be acceptable. The design was therefore changed to a secondary analysis of published Saudi field studies. The original title remains, while the methodology clearly identifies the source of every result.

The main problem addressed in this study is the lack of one clear picture showing how medication management, respiratory-care standardization, and hospital organization are related to cost efficiency in Saudi public hospitals.

## **1.3 Importance of the Study**

### **1.3.1 Scientific Importance**

The scientific value of this project comes from bringing together evidence that is usually discussed in separate fields. Medication, respiratory, and organizational interventions are compared through one framework. The analysis also distinguishes direct financial savings from lower resource use, technical efficiency, and clinical outcomes. This distinction matters because reduced resource use cannot be considered efficient if patient safety becomes worse.

### **1.3.2 Practical Importance**

The study gives hospital managers a list of measures that can be followed using routine data. These include antimicrobial use per 100 bed-days, pharmacist interventions, ventilator-bundle compliance, VAP per 1,000 ventilator-days, bed occupancy, delayed discharge, and hospital efficiency scores. The results may help hospitals design dashboards and choose improvement priorities. They also show the importance of cooperation between physicians, respiratory therapists, nurses, pharmacists, quality staff, and finance teams.

## **1.4 Objectives of the Study**

Main objective: To study the relationship between clinical resource optimization and cost efficiency in Saudi public-hospital ICUs by analyzing published Saudi field studies.

1. To describe Saudi evidence about medication optimization in critical care and its effect on resource use or cost.
2. To review the reported effects of respiratory and ventilator-care programs on infection, care processes, and cost.
3. To examine Saudi evidence about hospital organization and technical efficiency.
4. To compare the direction, size, and statistical strength of the reported results.
5. To suggest practical ways to measure and improve ICU resource efficiency.

## **1.5 Research Questions**

1. What changes in medication use and cost were reported after ICU medication-optimization programs?
2. What changes in respiratory care, ventilator outcomes, and cost were reported after structured programs?
3. What do Saudi studies report about hospital and ICU operational efficiency?
4. Do the selected studies show a similar relationship between resource optimization and cost efficiency?

5. What measures should Saudi public hospitals follow when they start ICU resource-optimization programs?

## 1.6 Research Hypotheses

Because the selected studies reported different outcomes, the hypotheses were assessed by comparing the direction and strength of their findings. The data were not suitable for a meta-analysis.

H1: Clinical resource optimization is linked with better cost or resource efficiency in Saudi public-hospital ICUs.

H1a: Medication-optimization programs are linked with lower medication use, lower medication cost, or more cost-saving interventions.

H1b: Respiratory resource-optimization programs are linked with better ventilator-care practices, fewer preventable complications, or lower related cost.

H1c: Governance and organizational changes are linked with better hospital or ICU efficiency indicators.

H0: Saudi field studies do not show a clear relationship between clinical resource optimization and efficiency outcomes.

| Study area                  | Objective      | Question      | Hypothesis |
|-----------------------------|----------------|---------------|------------|
| Medication optimization     | Objective 1    | Question 1    | H1a        |
| Respiratory optimization    | Objective 2    | Question 2    | H1b        |
| Organization and governance | Objective 3    | Question 3    | H1c        |
| Integrated effect           | Objectives 4-5 | Questions 4-5 | H1 / H0    |

**Table 1.1 Alignment of objectives, questions, and hypotheses**

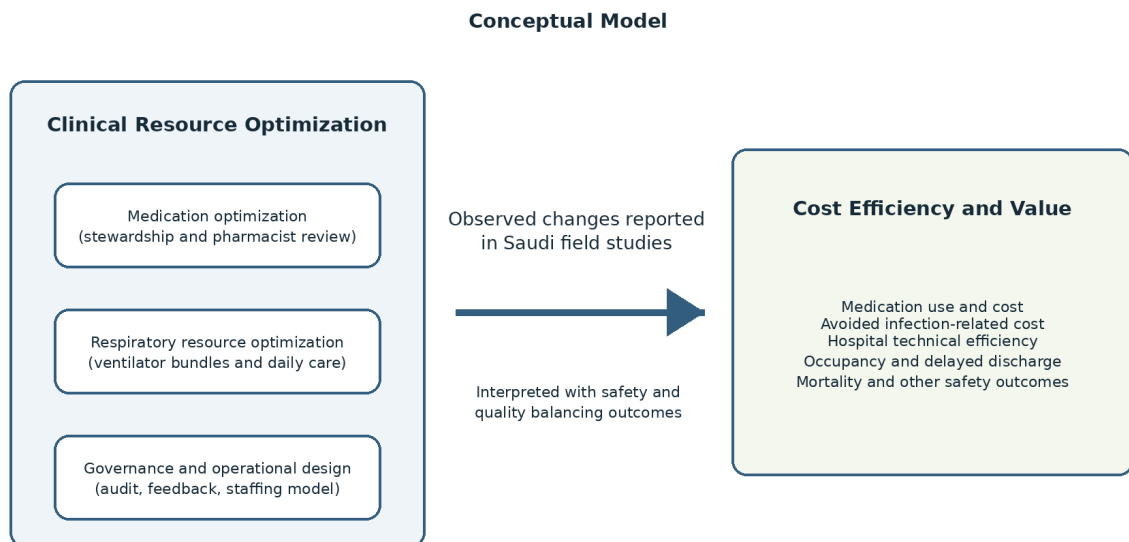
## 1.7 Operational Definitions

| Term                              | Definition used in this study                                                                                                                                                                                                                                            |
|-----------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Clinical resource optimization    | A structured process that improves how medications, respiratory equipment, staff practices, and hospital capacity are used. In this study it is represented by stewardship, pharmacist review, ventilator-care bundles, audit and feedback, and organizational redesign. |
| Cost efficiency                   | Achieving the same or better service and outcomes with lower or more appropriate resource input. Measures include reported monetary savings, medication cost, technical-efficiency scores, occupancy, and avoidable complication-related cost.                           |
| Medication optimization           | Review and control of medication selection, dose, route, duration, duplication, and de-escalation.                                                                                                                                                                       |
| Respiratory resource optimization | Standardized care for mechanically ventilated patients, including prevention bundles, spontaneous awakening and breathing trials, and avoidance of unnecessary treatment.                                                                                                |
| Secondary field-data analysis     | Analysis of quantitative results already collected in empirical Saudi hospital studies. No new patient or staff data were collected for this project.                                                                                                                    |

**Table 1.2 Operational definitions**

## 1.8 Conceptual Framework

The framework groups clinical resource optimization into three areas: medication management, respiratory resource management, and organizational governance. Evidence from each area is considered against cost, resource use, technical efficiency, and operational performance, while patient outcomes remain part of the interpretation. A lower cost, by itself, is not evidence of efficiency if the quality of care declines.



**Figure 1.1 Conceptual model**

## 1.9 Scope of the Study

The study includes quantitative research from Saudi public, governmental, university, and national collaborative hospital settings. Its main focus is adult intensive care and related evidence about public-hospital efficiency. Studies published up to July 2026 were considered. International sources are used only to explain basic concepts. The numerical results in Chapter Four come from Saudi field studies.

## Chapter Two: Literature Review

### 2.1 Introduction

This chapter looks at the management ideas that support the study and then reviews the Saudi research that was chosen for it. The review is organized around cost efficiency and the three areas of resource optimization this project focuses on: medication management, respiratory care, and organizational governance.

### 2.2 Cost Efficiency in Healthcare

Cost efficiency does not simply mean spending less. A hospital can lower its spending by treating fewer patients, transferring complicated cases elsewhere, or cutting back on services, and none of that actually makes it more efficient. Real efficiency is about the relationship between what a hospital puts in and what it gets out. The inputs are things like beds, staff, medication, devices, and time, while the outputs are the patients treated, the procedures performed, the quality of care, survival, and how quickly patients are discharged. Alatawi et al. (2020) applied data envelopment analysis to examine how effectively Saudi public hospitals converted these inputs into services.

Inside the ICU specifically, cost tends to be tied to patient-days, ventilator-days, medication use, and complications that could have been prevented. Not every study reviewed here reported a full financial figure. Some gave cost per 100 bed-days, some estimated the cost avoided through infection prevention, and others relied on operational indicators instead. Because these are not the same type of measurement, this study does not attempt to combine them into a single overall total.

### 2.3 Theoretical Foundations

#### 2.3.1 Resource-Based View

The resource-based view argues that an organization's performance comes down to how well it manages its resources, not just how many resources it has (Barney, 1991). Two ICUs could be equipped with almost identical beds and machines and still end up with very different results. What usually explains the gap is not the equipment itself, but things like stronger protocols, better teamwork among staff, and more consistent review of how care is actually being delivered.

#### 2.3.2 Donabedian Structure-Process-Outcome Model

Donabedian's model breaks quality down into three linked parts: structure, process, and outcome. Structure covers the staff, policies, beds, and equipment already in place. Process is what actually happens day to day, things like stewardship rounds, ventilator checks, and how closely staff follow care bundles. Outcome is the result of all that, reflected in cost, infection rates, mortality, and length of stay. The point this model makes is that simply having a policy on paper is not enough; the policy only matters once it changes what staff actually do every day.

#### 2.3.3 Value and Cost Efficiency

The value-based view compares the outcomes patients get against the resources it took to get there. In an ICU, a drop in medication cost is only a good sign if care is still safe and delivered on

time. The same logic applies to bed occupancy: lower occupancy might mean patients are moving through the unit more smoothly, but it could also just mean beds are sitting empty. That is why cost figures need to be read alongside quality and access measures, not on their own.

## 2.4 Medication Optimization Evidence

### 2.4.1 Antimicrobial Stewardship in a Saudi Critical Care Unit

Haseeb et al. (2021) looked at a multidisciplinary antimicrobial stewardship program run in a 20-bed adult ICU at Ajyad Emergency Hospital in Makkah. They compared the nine months before the program started with the nine months after. The program itself combined leadership support, prescribing guidance, staff education, and audit and feedback during ward rounds. Because medication use and cost were both reported per 100 bed-days, the two periods could be compared in a fairly direct way.

Total antimicrobial use fell from 742.86 to 555.33 defined daily doses per 100 bed-days, roughly a 25% drop. The intravenous figure dropped even more sharply, from 293.43 to 164.41, close to 44%, and this change was statistically significant. Several individual drugs showed the same downward pattern. One complication was that linezolid was introduced partway through the study and pushed the total cost up. Once linezolid was taken out of the calculation, cost fell from SAR 38,723.72 to SAR 25,299.24 per 100 bed-days.

One thing worth flagging is that the article itself gives two different p-values for this linezolid-adjusted cost result: the text says  $p = 0.008$ , but the table says  $p = 0.086$ . Given that mismatch, this study reports the reduction as a finding without calling it statistically significant. Separately, ICU length of stay did not show a meaningful change.

### 2.4.2 Clinical Pharmacist Interventions

Althomali et al. (2022) looked at six months of clinical pharmacist interventions in the ICU at King Faisal Medical Complex in Taif, covering 165 patients and 404 interventions in total. According to the results table, 370 of these were accepted, which works out to 91.5%. Interestingly, another part of the article quotes 98.5% instead. This study goes with 91.5%, since that figure is the one that actually matches the reported numbers.

Of the 404 interventions, 169 (41.6%) were judged likely to save cost. The interventions themselves were fairly practical: stopping a drug once it had run unnecessarily long, adjusting a dose for kidney function, stopping a drug that had no clear reason to be prescribed, catching duplicate therapy, and managing drug interactions. What the authors did not do was work out an actual dollar figure for the savings, so this study can point to pharmacist review as valuable without being able to attach a specific financial number to it.

## 2.5 Respiratory Resource Optimization Evidence

### 2.5.1 Ventilator-Care Bundle and VAP Cost

Bukhari et al. (2012) ran a prospective study in the adult ICU at Hera General Hospital in Makkah, covering 2,747 patients. The ventilator-care bundle they used combined raising the head

of the bed, a daily sedation interruption paired with a weaning-readiness check, peptic-ulcer prevention, and deep-vein-thrombosis prevention. Compliance with the bundle averaged 78.9% overall, but it climbed steadily over the year, starting at 30% in January and reaching 100% by December.

By 2010, the VAP rate had come down to 1.98 per 1,000 ventilator-days, which the authors describe as 1.41 lower than the 2009 rate, putting the 2009 figure at roughly 3.39 and the overall reduction at about 41.6%. Alongside this, the study estimated a one-year cost saving of USD 154,930, and higher bundle compliance was significantly linked to the lower VAP rate ( $p = 0.001$ ). It is worth keeping in mind that this cost figure comes from a single hospital in 2010, so it should be read as one data point rather than a current national estimate.

### 2.5.2 National Mechanical-Ventilation Improvement Collaborative

Arabi et al. (2023) describe a much larger, national-scale project aimed at improving care for mechanically ventilated patients, spanning 42 ICUs across 26 Saudi hospitals, more than 83,000 ventilator-days, and 8,523 patients. Month over month, compliance improved across several practices: subglottic suctioning rose by 3.5%, spontaneous awakening trials by 2.1%, and spontaneous breathing trials by 1.9%, while use of neuromuscular blockers fell by 2.5% a month.

Mortality started at 30.4% and dropped by 1.6% each month, which is a meaningful trend. That said, not everything moved in the expected direction: ventilator-associated events did not decrease, and neither ventilation duration nor ICU length of stay changed. Taken together, this is a useful reminder that day-to-day care practices can genuinely improve even while some of the resource outcomes you would expect to follow don't shift within the study period.

## 2.6 Organizational and Hospital Efficiency Evidence

### 2.6.1 Technical Efficiency of Saudi Public Hospitals

Alatawi et al. (2020) used 2017 Ministry of Health data and data envelopment analysis to evaluate 91 Saudi public hospitals. The finding that stands out is that 69 of them, or 75.8%, were technically inefficient, with an average efficiency score of 0.76 under constant returns to scale. Put simply, the model suggests the average hospital could cut its inputs by around 24% and still produce the same output, if it operated the way the most efficient hospitals do.

Just 22 hospitals reached both technical and scale efficiency. Smaller hospitals tended to score better than larger ones, and hospitals in the central region outperformed those in the western region. The study does not point to any single ICU practice as the fix, but it does make clear that how beds, staff, and other resources get used varies a lot from one public hospital to another.

### 2.6.2 ICU Operating Model and Key Performance Indicators

Alarifi et al. (2024) compared a medical/surgical ICU model against a later mixed ICU model, using 2018-2022 data from King Khalid University Hospital in Riyadh. Across the two periods, the standardized mortality ratio dropped from 0.575 to 0.399, ICU length of stay fell from 4.989 to 4.481 days, occupancy dropped from 91.00% to 72.08%, and delayed discharge decreased from 34.59% to 23.31%. Of these, only the change in occupancy reached statistical significance.

These numbers need to be read carefully rather than taken at face value. Lower occupancy could mean better access and less pressure on the unit, but it could just as easily mean beds are going unused. The safest approach is to look at occupancy alongside mortality, length of stay, delayed discharge, and admission activity, rather than on its own.

| Study                   | Setting                                 | Design/sample                                          | Main outcomes                                      |
|-------------------------|-----------------------------------------|--------------------------------------------------------|----------------------------------------------------|
| Bukhari et al. (2012)   | Hera General Hospital, Makkah           | Prospective ICU field study; 2,747 patients            | Ventilator bundle compliance, VAP, estimated cost  |
| Alatawi et al. (2020)   | 91 MOH public hospitals                 | Data envelopment analysis using 2017 official data     | Technical and scale efficiency                     |
| Haseeb et al. (2021)    | Ajyad Emergency Hospital ICU, Makkah    | Quasi-experimental, 9 months before/after              | Antimicrobial use, cost, LOS                       |
| Althomali et al. (2022) | King Faisal Medical Complex ICU, Taif   | Retrospective; 165 patients, 404 interventions         | Pharmacist interventions and potential cost saving |
| Arabi et al. (2023)     | 42 ICUs in 26 Saudi hospitals           | National prospective quality-improvement collaborative | Ventilator-care processes, VAE, mortality, LOS     |
| Alarifi et al. (2024)   | King Khalid University Hospital, Riyadh | Retrospective comparison, 2018-2022                    | SMR, LOS, occupancy, delayed discharge             |

**Table 2.1 Summary of selected Saudi empirical studies**

## 2.7 Comparison of the Evidence Domains

| Domain           | Measures                                                | Strength                                                              | Main limitation                                                                     |
|------------------|---------------------------------------------------------|-----------------------------------------------------------------------|-------------------------------------------------------------------------------------|
| Medication       | Direct use and some cost measures                       | Clear reduction in use, but financial saving was only partly measured | Mostly single-center studies, with inconsistent reporting in one article            |
| Respiratory care | Process compliance, VAP, cost estimate, mortality       | Large improvement projects with important clinical outcomes           | Some outcomes did not improve, and the cost evidence came from an older local study |
| Organization     | Technical efficiency, occupancy, LOS, delayed discharge | Shows opportunities for better hospital operations                    | One study was not limited to ICUs, and cause and effect cannot be confirmed         |

**Table 2.2 Comparison of the evidence domains**

## 2.8 Research Gap

Saudi research provides useful field evidence, but no single study combines medication, respiratory, and organizational resource management in one national model of ICU cost. The studies also use different units and cover different periods, which limits direct comparison. This project addresses part of that gap by placing the findings side by side, retaining the original units, and stating clearly when statistical significance, financial value, or cause and effect cannot be confirmed.

## **2.9 Chapter Summary**

The literature points to three practical routes to greater efficiency: better medication decisions, standardized respiratory care, and stronger organizational control. The general direction of the evidence is positive, but the size and statistical strength of the effects are not consistent. A structured secondary analysis is therefore more appropriate than reducing the experience of Saudi ICUs to a single percentage.

## Chapter Three: Research Methodology

### 3.1 Introduction

This chapter sets out how the Saudi studies were identified, selected, checked, and compared. A secondary-data approach was chosen because the project did not require a questionnaire and direct hospital records were unavailable. It also ensures that published findings are not presented as data collected by the student.

### 3.2 Research Design

The research design was a structured secondary analysis of quantitative findings from Saudi hospital studies. It was not treated as a full systematic review or meta-analysis because the outcomes were too different to pool statistically. The work involved defining the research question, locating relevant studies, applying the eligibility criteria, extracting the required data, calculating transparent percentage changes, and comparing results across the three topic areas.

**Methodological disclosure:** All numerical results in Chapter Four were reported in the cited original studies or were calculated directly from their published values. No new patients, staff responses, or hospital financial records were collected by the student.

### 3.3 Research Community

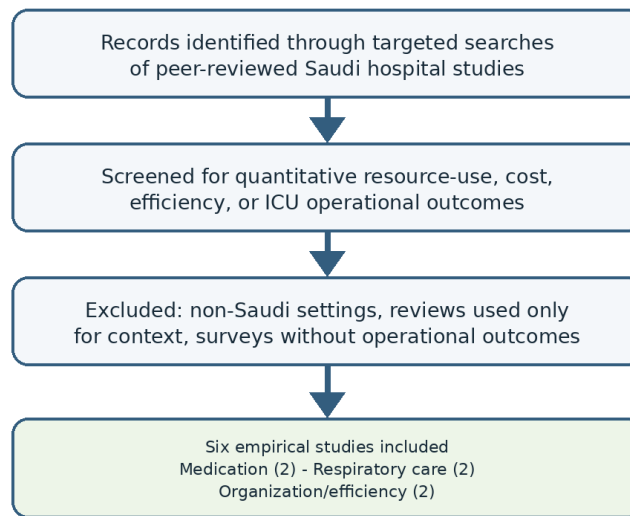
The research community included quantitative studies from Saudi public, governmental, university, and national collaborative hospitals. The studies had to report information about clinical resource use, cost, efficiency, or ICU operational outcomes.

### 3.4 Study Sample and Sample Determination

Six studies were selected purposively because each provided evidence relevant to the framework. Two examined medication management, two examined respiratory care, and two examined hospital or ICU organization. No patient sample-size formula was applied because the unit of analysis was the published study rather than an individual patient.

### 3.5 Search and Selection Process

Searches used terms such as Saudi Arabia, intensive care, public hospital, resource use, cost, antimicrobial stewardship, clinical pharmacist, mechanical ventilation, ventilator bundle, efficiency, occupancy, and delayed discharge. Journal websites, PubMed records, and open full-text sources were used to check the study details. Ministry of Health reports were used for background information, but they were not included as intervention studies unless they contained an empirical analysis.

**Evidence Selection for the Secondary Field-Data Analysis****Figure 3.1 Evidence-selection process****3.6 Eligibility Criteria**

| Criterion       | Included                                                                                                            | Excluded                                                                      |
|-----------------|---------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------|
| Country/setting | Saudi hospital setting; public, governmental, university, or national public-sector collaborative                   | Non-Saudi study; private-only setting without relevance to public hospitals   |
| Design          | Primary quantitative empirical study or quality-improvement evaluation                                              | Review, editorial, opinion, or purely qualitative study used as a data source |
| Topic           | Medication, respiratory, organizational, cost, or efficiency outcome related to ICU or public-hospital resource use | No measurable resource, efficiency, cost, or operational outcome              |
| Reporting       | Sufficient numerical information to extract a result                                                                | Only general statements without extractable data                              |
| Population      | Adult ICU or broader public-hospital efficiency evidence relevant to ICU management                                 | Pediatric-only evidence unless directly necessary for context                 |

**Table 3.1 Eligibility criteria****3.7 Data Collection Procedures**

A standard data-extraction sheet was used for all studies. It recorded the author and year, hospital and city, study design, study period, sample size or data volume, intervention, outcome definition, baseline and follow-up values, statistical results, currency, and main limitations. When possible, the numbers were checked against the tables in the original article.

| Data group           | Items extracted                                                     |
|----------------------|---------------------------------------------------------------------|
| Study identification | Author, year, title, journal, DOI                                   |
| Setting              | Hospital, city, ICU type, public-sector status                      |
| Design               | Prospective, retrospective, quasi-experimental, DEA, or comparative |

| Data group           | Items extracted                                                               |
|----------------------|-------------------------------------------------------------------------------|
| Sample               | Patients, interventions, hospitals, ventilator-days, or study years           |
| Optimization domain  | Medication, respiratory care, or organization                                 |
| Outcome              | Cost, consumption, infection, mortality, LOS, occupancy, technical efficiency |
| Statistics           | Baseline, follow-up, relative change, p-value or confidence interval          |
| Interpretation notes | Internal inconsistencies, missing monetary values, and limits on causality    |

Table 3.2 Data items extracted from each study

### 3.8 Data Analysis

The findings were compared descriptively because the outcomes could not be combined in one statistical analysis. When a study reported a baseline and a follow-up value, the percentage change was calculated using the following formula:

$$\text{Percentage change} = ((\text{follow-up value} - \text{baseline value}) / \text{baseline value}) \times 100$$

A negative value indicates a decrease. Where helpful, Chapter Four presents the same result as a percentage reduction. All p-values and confidence intervals come from the original articles. No additional significance tests were carried out because patient-level and monthly source data were unavailable.

Each hypothesis was classified as supported, partly supported, or not supported. Support required a generally positive pattern within the relevant studies and at least one direct measure of cost or efficiency. Partial support was assigned when care processes improved but the evidence on cost or resource use remained mixed or incomplete.

### 3.9 Quality and Interpretation Checks

| Check                    | Application                                                                                              |
|--------------------------|----------------------------------------------------------------------------------------------------------|
| Source authenticity      | Check the original journal page, article table, DOI, or official record.                                 |
| No double counting       | Count repeated reports of the same project only once.                                                    |
| Unit preservation        | Keep each result in its original unit, such as SAR, USD, DDD/100 bed-days, or VAP/1,000 ventilator-days. |
| No false pooling         | Do not average different outcomes or create one national saving figure.                                  |
| Balance outcomes         | Report mortality, VAE, length of stay, and other quality outcomes when available.                        |
| Inconsistency disclosure | Report differences between the article text and tables instead of choosing the more favorable value.     |

| Check          | Application                                                                           |
|----------------|---------------------------------------------------------------------------------------|
| Causal caution | Use cautious wording unless the original study design supports a stronger conclusion. |

**Table 3.3 Quality and interpretation checks**

### 3.10 Study Scope and Limitations

Focusing on Saudi evidence improves the project's relevance to the local healthcare system, but the scope has clear limits. Only six studies were included, and their methods and measures differed. Study periods ranged from 2010 to 2022, while reported costs were not adjusted for inflation. Some evidence came from a single hospital, one study covered public hospitals rather than ICUs alone, and several outcomes measured processes instead of direct cost. As a result, the studies cannot support one national estimate of cost savings.

### 3.11 Ethical Considerations

The study used published results that were already available to the public. It did not use patient names, identifiable information, or confidential hospital records. Each original study was responsible for its own ethics approval. This project focused on correct citation, clear calculations, and avoiding invented data.

## Chapter Four: Data Analysis, Findings, and Discussion

### 4.1 Introduction

This chapter reports the findings from the six selected Saudi studies. Results are organized under medication management, respiratory care, and organizational efficiency, followed by an assessment of the hypotheses and a comparison of the main patterns.

### 4.2 Characteristics of the Included Evidence

| Study                  | Setting                                            | Design                                | Sample/data volume                      | Domain       |
|------------------------|----------------------------------------------------|---------------------------------------|-----------------------------------------|--------------|
| Bukhari et al., 2012   | Adult ICU, Hera General Hospital, Makkah           | Prospective longitudinal              | 2,747 patients; 12 months               | Respiratory  |
| Alatawi et al., 2020   | Saudi MOH public hospitals                         | DEA, official 2017 data               | 91 hospitals                            | Organization |
| Haseeb et al., 2021    | 20-bed adult ICU, Ajyad Emergency Hospital, Makkah | Quasi-experimental                    | 684 pre admissions; 623 post admissions | Medication   |
| Althomali et al., 2022 | ICU, King Faisal Medical Complex, Taif             | Retrospective                         | 165 patients; 404 interventions         | Medication   |
| Arabi et al., 2023     | 42 ICUs in 26 Saudi hospitals                      | Prospective national QI collaborative | 83,153 ventilator-days; 8,523 patients  | Respiratory  |
| Alarifi et al., 2024   | King Khalid University Hospital, Riyadh            | Retrospective comparative             | 2018-2022 KPI data                      | Organization |

**Table 4.1 Characteristics of included studies**

The evidence varied considerably in scale. Four studies were conducted in one center or hospital, one examined 91 public hospitals, and one national project included 42 ICUs. This provides a broader picture of the Saudi setting, but the differences also prevent the findings from being combined into a single pooled result.

### 4.3 Medication Optimization Findings

| Outcome                                        | Reported values                                 | Change                     | Statistical note                     | Source                 |
|------------------------------------------------|-------------------------------------------------|----------------------------|--------------------------------------|------------------------|
| Total antimicrobial use                        | 742.86 to 555.33 DDD/100 bed-days               | 25.2% reduction            | p = 0.110                            | Haseeb et al., 2021    |
| IV antimicrobial use                           | 293.43 to 164.41 DDD/100 bed-days               | 44.0% reduction            | p = 0.038                            | Haseeb et al., 2021    |
| Ceftriaxone use                                | 94.32 to 16.68 DDD/100 bed-days                 | 82.3% reduction            | p = 0.008                            | Haseeb et al., 2021    |
| Vancomycin use                                 | 24.73 to 8.40 DDD/100 bed-days                  | 66.0% reduction            | p = 0.008                            | Haseeb et al., 2021    |
| Antimicrobial cost excluding linezolid         | SAR 38,723.72 to SAR 25,299.24 per 100 bed-days | 34.7% reduction            | Table p = 0.086; narrative p = 0.008 | Haseeb et al., 2021    |
| Potential cost-saving pharmacist interventions | 169 of 404 interventions                        | 41.6% of all interventions | No monetary total calculated         | Althomali et al., 2022 |
| Accepted pharmacist interventions              | 370 of 404                                      | 91.5%                      | Descriptive                          | Althomali et al., 2022 |

**Table 4.2 Medication optimization findings**

The medication studies offer the most direct evidence of changes in resource use. Intravenous antimicrobial use fell by 44%, a statistically significant result. Total antimicrobial use also declined, although that comparison was not statistically significant. The linezolid finding shows

why a total cost figure needs context: introducing an expensive but clinically necessary drug may raise spending even when avoidable use of other drugs falls.

The pharmacist study shows how medication efficiency may improve during routine ICU work. More than two-fifths of the interventions had the potential to save cost. Since the authors did not calculate a value in Saudi riyals, the finding supports the contribution of ICU pharmacists but cannot justify a claim about a specific amount saved.

#### 4.4 Respiratory Resource Optimization Findings

| Outcome                          | Reported value                                                   | Direction                    | Statistical note                             | Source               |
|----------------------------------|------------------------------------------------------------------|------------------------------|----------------------------------------------|----------------------|
| VAP bundle compliance            | 30% in January to 100% in December; annual overall 78.9%         | Large compliance improvement | VAP correlation $p = 0.001$                  | Bukhari et al., 2012 |
| VAP rate                         | Estimated 3.39 in 2009 to 1.98 in 2010 per 1,000 ventilator-days | 41.6% reduction              | Based on reported absolute reduction of 1.41 | Bukhari et al., 2012 |
| Estimated annual cost reduction  | USD 154,930                                                      | Reported by original study   | Local 2010 estimate                          | Bukhari et al., 2012 |
| Subglottic suctioning compliance | Monthly IRR 1.035                                                | 3.5% monthly increase        | $p = 0.0148$                                 | Arabi et al., 2023   |
| Spontaneous awakening trials     | Monthly IRR 1.021                                                | 2.1% monthly increase        | $p = 0.0003$                                 | Arabi et al., 2023   |
| Spontaneous breathing trials     | Monthly IRR 1.019                                                | 1.9% monthly increase        | $p = 0.0001$                                 | Arabi et al., 2023   |
| Neuromuscular blocker use        | Monthly IRR 0.975                                                | 2.5% monthly decrease        | $p = 0.0341$                                 | Arabi et al., 2023   |
| ICU mortality                    | Baseline 30.4%                                                   | 1.6% monthly decrease        | $p = 0.0067$                                 | Arabi et al., 2023   |
| VAE, MV duration, ICU LOS        | No significant improvement                                       | Mixed outcome                | VAE $p = 0.2812$                             | Arabi et al., 2023   |

**Table 4.3 Respiratory resource optimization findings**

Both respiratory studies support daily care bundles and regular monitoring of compliance. In the Bukhari study, higher compliance was associated with a lower VAP rate and an estimated cost reduction. The national project showed that daily ventilator-care practices could improve across a large group of hospitals. Still, ventilator-associated events, ventilation duration, and ICU length of stay did not decline, meaning that stronger compliance was not followed by immediate improvement in every measured outcome.

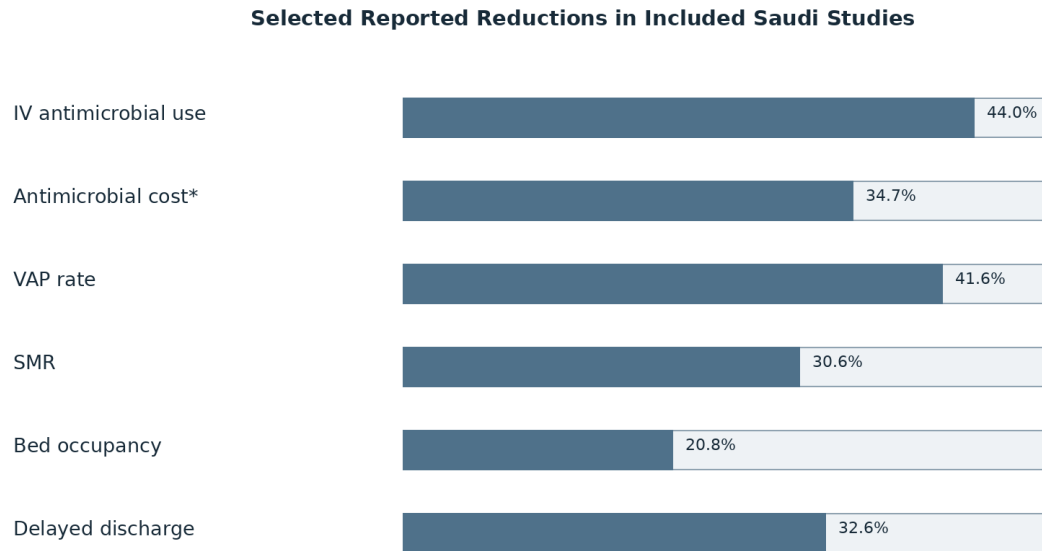
#### 4.5 Organizational and Efficiency Findings

| Outcome                           | Values              | Interpretation                                                | Statistical note                | Source               |
|-----------------------------------|---------------------|---------------------------------------------------------------|---------------------------------|----------------------|
| Technically inefficient hospitals | 69 of 91 hospitals  | 75.8%                                                         | DEA using 2017 MOH data         | Alatawi et al., 2020 |
| Mean CRS efficiency score         | 0.76                | Estimated 24% input-reduction opportunity at unchanged output | Input-oriented interpretation   | Alatawi et al., 2020 |
| Efficient hospitals               | 22 of 91            | 24.2%                                                         | Technically and scale efficient | Alatawi et al., 2020 |
| Standard mortality ratio          | 0.575 to 0.399      | 30.6% reduction                                               | $p = 0.169$                     | Alarifi et al., 2024 |
| ICU length of stay                | 4.989 to 4.481 days | 10.2% reduction                                               | $p = 0.329$                     | Alarifi et al., 2024 |
| Bed occupancy                     | 91.00% to 72.08%    | 20.8% reduction                                               | $p < 0.001$                     | Alarifi et al., 2024 |
| Delayed ICU discharge             | 34.59% to 23.31%    | 32.6% reduction                                               | $p = 0.196$                     | Alarifi et al., 2024 |

**Table 4.4 Organizational and efficiency findings**

The hospital-efficiency study provides the broadest national picture. Its average score of 0.76 indicates room for more effective use of resources, but the score does not tell an individual ICU what it should reduce. Hospitals still need to examine their own services and constraints. The ICU operating-model study also reported movement in several indicators, although only the difference in occupancy was statistically significant.

## 4.6 Comparative Descriptive Analysis



\* Cost excluding newly introduced linezolid. Values are descriptive and were not pooled.

**Figure 4.1 Selected reported reductions in included Saudi studies**

Figure 4.1 places several reported percentage reductions on the same chart, but the bars are not directly comparable because they represent different outcomes. Medication use, VAP, mortality risk, occupancy, and delayed discharge measure different things. The chart is intended only to show that improvements were reported in each of the three evidence areas.

## 4.7 Hypothesis Testing

| Hypothesis | Statement                                          | Decision                | Reason                                                                                                                                                    |
|------------|----------------------------------------------------|-------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|
| H1         | Clinical resource optimization improves efficiency | Supported directionally | Most studies reported better cost, resource use, or operational results. However, the studies were too different to calculate one combined causal effect. |

| Hypothesis | Statement                                                      | Decision            | Reason                                                                                                                                                                          |
|------------|----------------------------------------------------------------|---------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| H1a        | Medication optimization improves medication cost/resource use  | Supported           | IV antimicrobial use decreased significantly. Cost was lower when linezolid was excluded, and 41.6% of pharmacist interventions were linked with possible cost saving.          |
| H1b        | Respiratory optimization improves resource/clinical efficiency | Partially supported | One study reported lower VAP and estimated cost. The national project improved care processes and mortality, but VAE, ventilation duration, and length of stay did not improve. |
| H1c        | Governance/organization improves efficiency indicators         | Partially supported | The national study found a large efficiency gap. The mixed ICU model reduced occupancy significantly, but the other changes were not statistically significant.                 |
| H0         | No consistent relationship                                     | Not supported       | Most results were positive, although the strength and type of evidence differed between studies.                                                                                |

Table 4.5 Synthesis of hypotheses

## 4.8 Discussion

### 4.8.1 Medication Management

The medication findings indicate that stewardship works through repeated clinical review, not simply through restrictions on prescribing. The programs combined leadership support, local guidance, education, audit, and feedback, influencing both hospital processes and bedside decisions. They also highlight the difference between medication volume and medication price. Spending may rise when a costly but appropriate drug is introduced, even if unnecessary use of other medication falls.

The pharmacist study offers practical examples from everyday ICU care. Renal-dose adjustment and stopping medication that has continued longer than necessary can reduce risk as well as cost. Its main weakness is the absence of a calculated financial value. Future Saudi studies could record the price of avoided doses and explain the method used to calculate cost avoidance.

#### 4.8.2 Respiratory Care

The VAP-bundle study reported clinical and financial benefits, linking bundle compliance with a lower infection rate and an estimated reduction in cost. However, it was a single-center study published in 2012. Before applying the reported USD figure to a current budget, hospitals would need to update local estimates for VAP treatment, ICU days, and inflation.

The national project was more recent and covered many ICUs, showing that standardized practices can be introduced across different hospitals. The lack of improvement in ventilator-associated events, ventilation duration, and length of stay should not be read as evidence that the project had no value. Mortality improved and some unnecessary or harmful practices declined. Changes in resource use may require a longer follow-up period, stronger implementation, or better adjustment for differences between patients.

#### 4.8.3 Organizational Efficiency

The hospital-efficiency findings suggest that differences in resource use are not explained only by patient needs. Some hospitals produced similar services with fewer inputs. Even so, an efficiency score cannot identify the bedside practice that should change, so it should prompt a local review rather than automatic budget cuts. The ICU-model findings require similar care: lower occupancy may reflect better patient flow, but managers also need to examine refused admissions, cancelled surgery, staffing, and seasonal demand.

#### 4.8.4 Integrated Interpretation

Across the six studies, a consistent lesson is that improvement programs are stronger when clear protocols are combined with measurement and teamwork. A policy on paper is not enough. The programs reporting progress relied on daily review, audit, feedback, compliance monitoring, or changes in unit organization. ICU resource management is therefore better understood as continuous improvement than as a one-time cost-cutting exercise.

### 4.9 Recommendations

1. Develop an ICU dashboard that reports medication use and cost per 100 bed-days, respiratory outcomes per 1,000 device-days, and direct cost per patient-day.
2. Strengthen antimicrobial stewardship through audit, feedback, renal-dose review, IV-to-oral conversion, and de-escalation.
3. Include a clinical pharmacist in regular ICU rounds and record both the clinical result and the actual financial value of accepted interventions.
4. Monitor spontaneous awakening trials, spontaneous breathing trials, subglottic suctioning when appropriate, head-of-bed elevation, and use of neuromuscular blockers.
5. Report VAP, ventilator-associated events, and bundle compliance together so that process improvement can be connected with patient outcomes.
6. Review bed occupancy and delayed discharge together with access measures. Low occupancy should not automatically be considered efficient.

7. Use the same cost definitions across months and hospitals. Report medication purchase cost, avoided cost, and estimated cost avoidance separately.
8. When changing the ICU operating model, monitor mortality, length of stay, readmission, occupancy, delayed discharge, and staffing together.
9. Future Saudi multicenter studies should use a common minimum dataset so their results can be combined more reliably.

#### **4.10 Study Limitations**

Because this project did not collect new hospital data, its results cannot be presented as findings from one new sample. The six studies differ in method, year, hospital setting, and unit of measurement, and their cost figures were not adjusted for inflation. One article also reports two p-values for the same cost outcome. The organizational evidence cannot establish that ICU clinical practice alone caused the observed changes. Finally, publication bias is possible because successful projects may be more likely to appear in journals than unsuccessful ones.

#### **4.11 Conclusion**

Overall, the Saudi evidence shows a positive association between organized resource management and cost or operational efficiency. Antimicrobial stewardship reduced medication use and produced a lower cost after linezolid was excluded. Respiratory-care bundles improved compliance and, in one hospital, reduced VAP and estimated cost. The national ventilation project improved daily care practices and mortality, although several resource outcomes remained unchanged. Evidence on hospital and ICU management also revealed efficiency differences and practical areas for improvement.

The central lesson is not that hospitals should simply use fewer resources. Instead, resources should follow patient need, supported by clear protocols, appropriate indicators, regular review, and continued monitoring of patient outcomes. Over time, this approach is more likely to improve efficiency than across-the-board budget reductions.

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## Appendices

### Appendix A: Data-Extraction Form

| Field                | Information recorded                                                  |
|----------------------|-----------------------------------------------------------------------|
| Study identification | Author, year, journal, DOI                                            |
| Setting              | Hospital, city, public-sector type, ICU type                          |
| Design and period    | Prospective/retrospective/quasi-experimental/DEA and dates            |
| Sample               | Patients, hospitals, interventions, bed-days, ventilator-days         |
| Intervention         | Medication, respiratory, or organizational optimization               |
| Outcome unit         | SAR, USD, DDD/100 bed-days, rate/1,000 device-days, score, percentage |
| Baseline value       | Exact published value                                                 |
| Follow-up value      | Exact published value                                                 |
| Calculated change    | Formula and result                                                    |
| Statistical evidence | p-value, confidence interval, or descriptive only                     |
| Balancing outcomes   | Mortality, LOS, VAE, readmission, or safety                           |
| Source inconsistency | Narrative/table differences or missing data                           |
| Interpretation       | Cost effect, resource effect, process effect, or mixed                |

**Appendix Table A1 Data-extraction form**

### Appendix B: Derived Calculations

| Outcome                          | Calculation                                      | Result                         |
|----------------------------------|--------------------------------------------------|--------------------------------|
| Haseeb: total antimicrobial use  | $(555.33 - 742.86) / 742.86 \times 100$          | -25.24%                        |
| Haseeb: IV antimicrobial use     | $(164.41 - 293.43) / 293.43 \times 100$          | -43.97%                        |
| Haseeb: cost excluding linezolid | $(25,299.24 - 38,723.72) / 38,723.72 \times 100$ | -34.67%                        |
| Bukhari: implied 2009 VAP rate   | $1.98 + 1.41$                                    | 3.39 per 1,000 ventilator-days |
| Bukhari: VAP reduction           | $(1.98 - 3.39) / 3.39 \times 100$                | -41.59%                        |
| Alarifi: SMR                     | $(0.399 - 0.575) / 0.575 \times 100$             | -30.61%                        |
| Alarifi: ICU LOS                 | $(4.481 - 4.989) / 4.989 \times 100$             | -10.18%                        |
| Alarifi: occupancy               | $(72.08 - 91.00) / 91.00 \times 100$             | -20.79%                        |
| Alarifi: delayed discharge       | $(23.31 - 34.59) / 34.59 \times 100$             | -32.61%                        |

**Appendix Table A2 Derived percentage-change calculations**

### Appendix C: Research Integrity Notes

- The original approved title was kept on the cover.
- The subtitle and methods clearly state that the project is a secondary analysis of published Saudi field studies.
- No questionnaire was used.
- No hospital data were invented or presented as data collected by the student.
- Every numerical result is linked to a cited study or to a calculation based on published values.
- Differences between article text and tables were reported.
- The six studies were not combined into an unsupported national cost estimate.
- The supervisor should confirm that the university accepts the secondary-data design before final submission.