

Diagnosis-Related Group - Based Case-Mix Index and Hospital Efficiency: A Systematic Review

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Abstract: Fair comparison of hospital efficiency requires adjustment for differences in patient complexity and resource needs. **Objective:** This systematic review synthesized how Diagnosis-Related Group (DRG)-based case-mix measures have been used in hospital efficiency assessment, resource allocation, and payment reform. **Methods:** Following PRISMA 2020 principles, PubMed, Scopus, Web of Science, and Google Scholar were searched for English-language studies published from January 2002 to December 2025. Eligible studies examined DRG or case-mix measures in inpatient hospital settings and reported efficiency, cost, resource-use, financing, or performance outcomes. **Results:** Ten studies met the inclusion criteria. Most used the Case-Mix Index (CMI) as a measure of clinical complexity and as a benchmark for payment or resource allocation. CMI was most consistently related to cost variation, inpatient expenditure, resource utilization, and length of stay. Fewer studies incorporated CMI directly into formal efficiency models. **Conclusion:** CMI is useful for risk-adjusted comparison of hospital performance, but it should not be interpreted as a standalone measure of efficiency. Strong coding systems, quality monitoring, and additional patient-level adjustment are needed for fair financing and policy use.

INTRODUCTION

A major challenge in comparing hospital performance, resource utilization, and efficiency across healthcare institutions lies in the heterogeneity of patient case complexity (Ash et al., 2000). Differences in disease severity, comorbidities, age, and demographic characteristics among patients lead to substantial variation in the intensity and type of healthcare services delivered. Consequently, meaningful evaluation of hospital performance requires measurement approaches that adequately account for these differences in patient complexity and clinical risk (Iezzoni, 2013; Newhouse, 1998). In particular, designing effective healthcare payment mechanisms necessitates accurate methods for quantifying treatment complexity based on patient case severity (Fetter et al., 1980; Mathauer & Wittenbecher, 2013).

Traditional indicators commonly used to evaluate hospital efficiency—such as healthcare expenditure, length of hospital stay, and mortality rates—are often insufficient to capture the multidimensional nature of hospital performance (Vitikainen et al., 2009). Hospitals at similar levels of care may appear to provide comparable services; however, they often treat patient populations with substantially different levels of clinical complexity. Failure to adjust for these differences may lead to biased performance assessments, inefficient policy decisions, and inequitable allocation of healthcare financing (Iezzoni, 2013), (Mathauer & Wittenbecher, 2012; World Health Organization, 2019). Within Diagnosis-Related Group (DRG)-based payment systems, international evidence suggests that relying solely on conventional cost indicators without incorporating case-mix adjustment mechanisms may inadequately explain variations in hospital expenditure (Hvenegaard et al., 2009). For instance, Pi et al. (2024) demonstrated in their study “*Using Case-Mix Index within DRG to Evaluate Variations in Hospitalization Costs at a Large Academic Medical Center*” that DRG cost weights explained only 37.2% of the observed variation in hospitalization costs. In contrast, the correlation between DRG-weighted Case-Mix Index (CMI) and resource utilization reached 61.0%. These findings indicate that although CMI plays an important role in explaining variations in healthcare costs and resource use, it should be interpreted as part of a broader analytical framework rather than as a standalone indicator (Pi et al., 2024).

To address this methodological limitation, the Case-Mix Index has been widely adopted as a standardized measure of patient complexity in hospital performance evaluation. The CMI represents the average relative weight of all cases treated in a healthcare facility during a specified period. It is calculated by summing the DRG relative weights of all treated cases and dividing the total by the number of patients treated. As such, the CMI reflects the overall clinical complexity of patients, the intensity of resource consumption, and the expected cost level associated with hospital services (Centers for Medicare & Medicaid Services, 2019, 2022). In most healthcare systems implementing DRG-based financing, the Case-Mix Index is derived from DRG relative weights, where a higher CMI indicates that a hospital provides more complex and resource-intensive services (Fetter et al., 1980). Since each case group’s relative weight represents the resources required for diagnosis and treatment relative to the average case, the CMI functions as a comprehensive indicator that enables comparison of both operational performance and clinical complexity across healthcare institutions (Busse et al., 2011; Forgione & Vermeer, 2002). Previous studies have highlighted the policy and managerial relevance of CMI in healthcare systems. Mathauer and Wittenbecher (2012, 2013) emphasized that DRG-based case-mix adjustment enables weighted comparisons of hospital performance

that incorporate differences in treatment complexity. Such systems improve transparency in healthcare financing, enhance financial efficiency, and support strategic purchasing mechanisms, particularly in low- and middle-income countries where financing distortions are more prevalent. Although implementation may face challenges related to hospital information systems, coding accuracy, and data availability, DRG-based case-mix adjustment provides a mechanism for more accurate and equitable reimbursement for complex medical cases (Mathauer & Wittenbecher, 2012).

Empirical evidence from high- and middle-income countries demonstrates a strong association between the Case-Mix Index and key hospital performance indicators, including hospital costs, length of stay, and human resource requirements (Hensen et al., 2005; Hvenegaard et al., 2009; Vitikainen et al., 2009). In specialized tertiary hospitals and academic medical centers, a CMI greater than 1 is generally interpreted as indicating that these institutions treat patients with higher clinical complexity and require more intensive resource utilization (Forgione & Vermeer, 2002; Pi et al., 2024). In DRG-based payment models, hospital reimbursement is typically determined by multiplying a base rate by the hospital's Case-Mix Index (Forgione & Vermeer, 2002; Hensen et al., 2005). This approach aligns financial incentives with patient complexity and resource needs, thereby promoting efficiency while maintaining access to care for more complex cases (Forgione & Vermeer, 2002; Vitikainen et al., 2009). Despite these advantages, implementing case-mix adjustment remains challenging in many low- and middle-income countries due to limitations in administrative data systems and clinical coding practices. As a result, estimates of treatment complexity are sometimes approximated rather than precisely measured (Mathauer & Wittenbecher, 2012, 2013; Zhao et al., 2018).

Recent studies have predominantly examined the DRG-based Case-Mix Index (CMI) either as a measure of case complexity or as a financing instrument, with limited efforts to integrate its role in relation to hospital efficiency and resource allocation within a unified analytical framework. Furthermore, methodological approaches to incorporating CMI into efficiency evaluation remain heterogeneous, and a consistent conceptual understanding has yet to be established. Therefore, this study addresses an underexplored area by systematically synthesizing the application of DRG-based CMI in relation to hospital efficiency, resource utilization, and financing. It is distinguished by conceptualizing CMI as an integrated analytical framework that links these dimensions, thereby providing a more comprehensive understanding of its role in health system performance evaluation.

Given the increasing global adoption of DRG-based payment systems, understanding how the Case-Mix Index has been applied in evaluating hospital efficiency and resource allocation is essential. Therefore, this study aims to synthesize existing evidence on the use of DRG-based Case-Mix Index measures in assessing hospital efficiency, cost variation, resource allocation, and financing mechanisms. By conducting a systematic review of studies published since 2002, this research seeks to (1) examine how the Case-Mix Index has been applied in evaluating hospital efficiency and identify the methodological approaches used in previous studies; (2) synthesize key findings regarding the relationship between CMI, hospital efficiency, cost control, and resource allocation; and (3) identify common patterns, limitations, and emerging research trends that may inform policy development for financing and performance evaluation in referral-level hospitals.

Theoretical Foundations of the Case-Mix Index: Risk Adjustment

The concept of the Case-Mix Index (CMI) is grounded in the theoretical framework of risk adjustment, which emphasizes that evaluations of healthcare performance, costs, and efficiency must account for differences in patient risk profiles and clinical complexity (Ash et al., 2000; Iezzoni, 2012, 2013). Risk adjustment emerged as a methodological response to the need for fair comparisons of healthcare providers, recognizing that variations in patient characteristics—such as disease severity, comorbidities, demographic factors, and clinical risk—significantly influence resource utilization and treatment outcomes.

The development of risk-adjustment methodologies gained particular importance in the United States during the 1960s and 1970s, when healthcare expenditures increased rapidly and policymakers began to seek more effective approaches for evaluating hospital efficiency and quality of care. During this period, John Wennberg and colleagues demonstrated substantial regional variations in healthcare utilization, hospital admission rates, and medical expenditures across different regions of the United States. Their research showed that these variations could not be fully explained by differences in population health status alone, highlighting the need for more sophisticated analytical frameworks to account for differences in patient case complexity (Wennberg, 1973; Wennberg & Gittelsohn, 1973).

The use of Case-Mix Index and risk adjustment expanded significantly following the introduction of the Medicare Prospective Payment System (PPS) in the United States in 1983. Under this system, hospitals were reimbursed based on predetermined payments derived from Diagnosis-Related Group (DRG) relative weights. This reform represented a major shift in healthcare financing, as it formally acknowledged that hospital payments must reflect differences in patient complexity and resource requirements (Centers for Medicare & Medicaid Services, 1983; Fetter et al., 1980). The implementation of DRG-based payment systems also reinforced the importance of case-mix adjustment in ensuring equitable reimbursement and meaningful performance comparisons across hospitals. Without appropriate case-mix adjustment, hospitals treating patients with more severe conditions and multiple comorbidities may be incorrectly classified as inefficient, despite providing more complex and resource-intensive care. Such misclassification may lead to distorted performance evaluations and create inequities in healthcare financing. Moreover, payment systems that fail to reflect actual resource utilization may generate unintended behavioral responses, including incentives for hospitals to avoid treating high-risk or complex patients (Ellis & McGuire, 1993, 1996; McGuire, 2000; Newhouse et al., 1980).

Consequently, the Case-Mix Index has evolved into a foundational concept within healthcare financing and performance evaluation, serving as a standardized mechanism for aligning hospital reimbursement, quality assessment, and resource allocation with patient complexity. As such, it represents not only a technical measurement tool but also a core policy instrument supporting equitable and efficient healthcare systems (Busse et al., 2011; Forgiione et al., 2004; Quentin et al., 2013). Furthermore, the Case-Mix Index (CMI) plays a critical mediating role in the evaluation of hospital efficiency. When efficiency is measured solely as a simple ratio of inputs (e.g., costs, labor) to outputs (e.g., service volume), differences in patient complexity are not accounted for, potentially leading to biased conclusions. By incorporating CMI, outputs can be weighted by case complexity, enabling the estimation of risk-adjusted efficiency. This approach provides a more accurate basis for comparing hospital performance under real-world conditions and allows for a more meaningful assessment of resource utilization. Accordingly, the theoretical framework of this study is grounded in risk adjustment theory, progressing through DRG classification to derive the Case-Mix Index, and

ultimately applying it to the evaluation of hospital efficiency as part of an integrated analytical chain. Within this framework, CMI is conceptualized not only as a measure of patient complexity but also as a key mediating variable that links resource utilization and performance evaluation in hospital settings (see Figure 1).

The Case-Mix Index is typically calculated by dividing the sum of the DRG relative weights for all treated cases within a hospital by the total number of cases treated during a given period. This calculation provides an aggregate measure of the average clinical complexity and expected resource intensity of the patient population served by the hospital (Centers for Medicare & Medicaid Services, 2019).

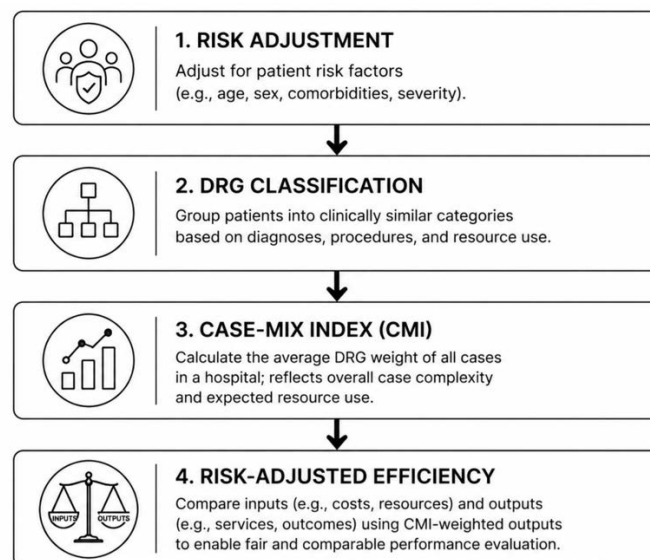


Figure 1. Conceptual Framework of Theoretical Constructs

$$CMI = \frac{\sum_{i=1}^n (w_i \times N_i)}{\sum_{i=1}^n N_i}$$

Figure 2. Formula for calculating the Case-Mix Index (CMI) (Centers for Medicare & Medicaid Services, 2019)

Table 1. Explanation of the Case-Mix Index (CMI) calculation formula (Centers for Medicare & Medicaid Services, 2019)

Indicator	Definition	Formula / Calculation	Interpretation
Case-Mix Index (CMI)	Indicates the level of treatment complexity of patients.	CMI = CMP / Discharges Discharges – number of patients discharged after receiving services	CMI > 1 → complex cases predominate. CMI < 1 → less complex cases predominate.
CMP – Case-Mix Point	Represents the aggregated case-mix value.	Formula = $\Sigma(C \times D)$	

	Formula= $\Sigma(C \times D)$	C- DRG relative weight D -number of cases	
DRG Relative Weight	Represents the relative cost and clinical complexity of a single case.	Calculated using the DRG code-specific weight.	Higher value → cases requiring more resources (baseline variable)
Cost per Weighted Case (CPWC)	Represents the cost per weighted case.	CPWC = OPEX / CMP (OPEX – Total operating expenditure)	
Standardized Efficiency (VMR / CMI)	Measures efficiency adjusted for case complexity.	Standardized efficiency = VMR / CMI	
Operating Expenditure per Discharge (OPEX per Discharge)	Represents the operating cost per patient discharge.	OPEX / per Discharge	
Value for Money Ratio (VMR)	Indicates the output generated per unit of cost.	VMR = CMP / OPEX	

METHODS

This study was conducted in accordance with the PRISMA 2020 (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines and was based on a predefined protocol specifying the study objectives, inclusion criteria, and methods for synthesis. The research process included several stages: formulation of the research question, database searching, preliminary and full screening, data extraction, and qualitative synthesis.

2.1 Data Sources and Search Strategy

The data required for this study were retrieved from the electronic databases Google Scholar, PubMed, Scopus, and Web of Science. Studies published in English between January 2002 and December 2025 were searched and identified. In addition, reference lists and citations of relevant review articles were manually screened using a traditional backward-searching approach. The search strategy included the keywords “Case Mix Index” or “CMI”, “Diagnosis-Related Groups” or “DRG-based payment”, “Hospital performance”, “Risk adjustment”, and “Hospital efficiency.” These keywords were used both individually and in combination, and the search syntax was adapted to the specific requirements of each database. The search was conducted iteratively to ensure comprehensive coverage. The review included peer-reviewed journal articles and conference proceedings. However, dissertations, master's and doctoral theses, as well as unpublished materials, were excluded from the analysis.

2.2 Inclusion and Exclusion Criteria

- o Setting: The included studies focused on inpatient hospital settings, including multi-hospital systems, specialized hospitals, and university hospitals. Studies evaluating performance at the hospital level were included, whereas studies focusing exclusively on outpatient services were excluded.

- o Methodology: The review included empirical studies that examined Case-Mix Index (CMI) or Diagnosis-Related Groups (DRG) in relation to hospital efficiency, resource utilization, costs, or performance outcomes. Studies lacking empirical evaluation, insufficient methodological information, or those published solely as reviews, editorials, or commentaries were excluded.
- o Outcomes: Studies were included if they reported outcomes related to CMI, including hospital costs, resource utilization, length of stay, or hospital performance indicators. Studies that did not provide sufficient data or did not evaluate hospital efficiency were excluded.
- o Timeframe: Only studies published between January 2002 and December 2025 were included in the review.
- o Language: The review included articles published in peer-reviewed journals in English. Grey literature was used only for reference screening purposes and was not included in the final analysis.

2.3 Study Selection and Screening

Study Selection Process

Although the application of DRG-based Case-Mix Index (CMI) in evaluating hospital resource utilization, financing, and efficiency has been widely studied internationally, existing studies vary considerably in terms of objectives, methodologies, and areas of application, and have developed in a fragmented manner. For example, some studies have examined CMI in the context of international comparisons (e.g., *Toward an International Case Mix Index for Comparisons of DRG-Based Health Care Systems*), while others have focused on payment reforms and financing mechanisms (e.g., OECD, China), and still others have addressed hospital costs, resource use, and efficiency analysis (e.g., Saudi Arabia, hospital cost variation, efficiency estimation).

In this study, over 350 sources were initially identified, and a total of **10 studies (n = 10)** were selected for analysis based on strict inclusion criteria following the PRISMA framework. The selection was guided by the following principles:

1. The study explicitly examined DRG and CMI in relation to hospital resource utilization, costs, or efficiency;
2. The study covered diverse countries and health system contexts (e.g., OECD countries, Europe, China, Saudi Arabia) to reflect cross-system variability;
3. Methodological diversity was ensured by including studies employing different approaches (e.g., cost analysis, efficiency analysis, policy evaluation), thereby avoiding a single analytical perspective;
4. The study considered CMI not in isolation, but in connection with DRG systems, financing mechanisms, or performance evaluation.

Although the final sample size is relatively small (n = 10), the selected studies are thematically representative, methodologically diverse, and relevant from both empirical and policy perspectives. This approach minimizes the risk of one-sided conclusions and enables a multidimensional synthesis of CMI applications across different contexts.

Screening process

All studies identified through the search process were imported into a reference management software, where duplicate records were removed. Subsequently, titles and abstracts were screened, followed by a full-text assessment based on the predefined eligibility criteria. Disagreements or uncertain cases during the screening process were resolved through discussion among the research team. Reasons for exclusion of full-text articles were systematically categorized. The most common reasons included studies that did not use DRG-based Case-Mix Index measures, studies with unclear methodological descriptions, insufficient information regarding data sources or statistical analyses, review articles, editorials, commentaries, and studies limited exclusively to outpatient care settings. These inclusion and exclusion criteria were based on the theoretical premise that Diagnosis-Related Groups (DRGs) and the Case-Mix Index represent indicators of patient severity and resource utilization within inpatient care settings. Furthermore, without appropriate risk adjustment, study findings may lead to biased comparisons across hospitals.

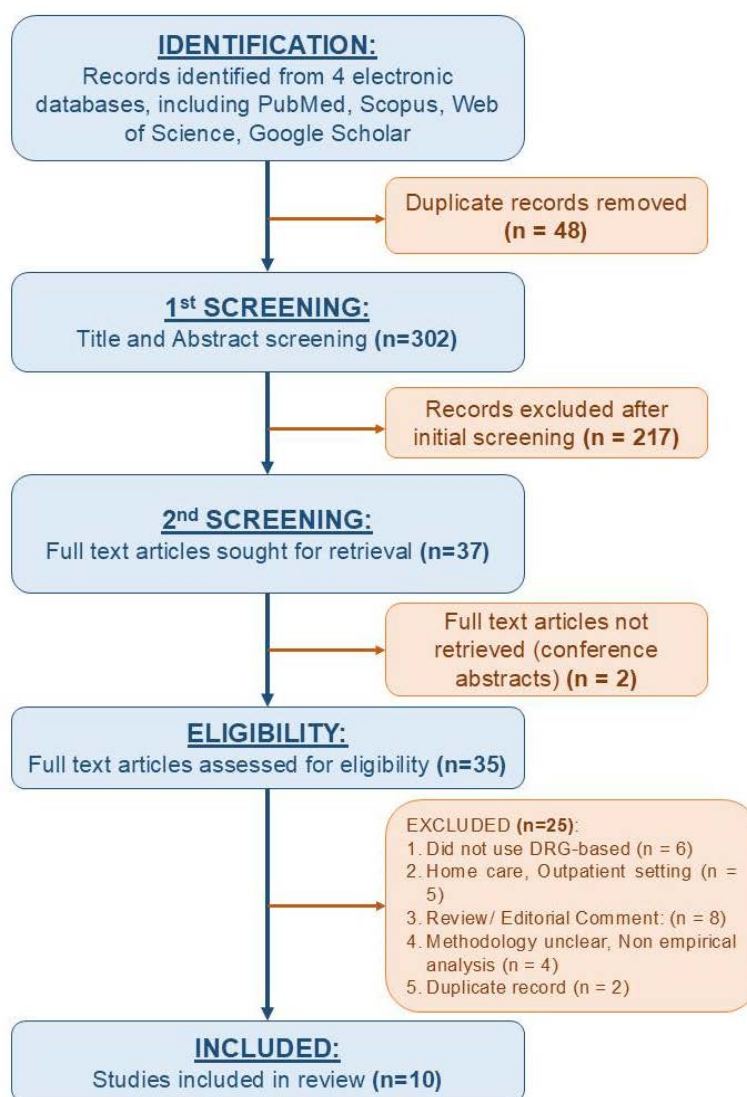


Figure 3. PRISMA flow diagram of the study selection process.

2.4 Data Extraction and Synthesis Methods

The methodological quality of the included studies was assessed based on several criteria, including study design, reliability of data sources, and transparency of statistical analysis methods. Following the PRISMA 2020 guidelines, a total of 350 records were initially identified. After removing duplicates, 302 articles were screened based on titles and abstracts. From these, 217 articles were excluded during the initial screening stage. The full texts of 37 articles were assessed for eligibility; however, the full text of 2 articles could not be retrieved. Among the remaining 35 articles, eligibility was evaluated according to the predefined criteria, resulting in the exclusion of 25 studies for the following reasons: absence of CMI measures ($n = 6$), outpatient-only settings ($n = 5$), review or editorial articles ($n = 8$), unclear methodology ($n = 4$), and duplicate studies ($n = 2$). Ultimately, 10 studies met the inclusion criteria and were included in the final systematic review. The study selection process is illustrated in the PRISMA 2020 flow diagram (Figure 2).

A standardized data extraction form was developed to collect relevant information from the selected studies. The extracted data included the general characteristics of each study, such as the research topic, year of publication, country or region, study design, study scope, use of CMI/DRG, and the performance indicators evaluated. To synthesize the application of DRG-based Case-Mix Index across studies, predefined variables were used for data extraction. These variables included the use of CMI as a complexity indicator, risk adjustment measure, payment or funding benchmark, and output adjustment measure. These categories enabled a comparative synthesis of how the Case-Mix Index was applied in different studies and methodological contexts.

The methodological quality of the included studies was assessed using the Joanna Briggs Institute (JBI) critical appraisal checklist. Each study was independently evaluated by two researchers. The evaluation criteria included study design, data quality, clarity of methodology, and reliability of reported outcomes. Data screening and extraction were conducted by two researchers independently, and any disagreements were resolved through consensus. Due to methodological heterogeneity among the included studies, a meta-analysis was not performed. Instead, the findings were synthesized using a qualitative narrative synthesis approach. The results were summarized in tables and compared across several analytical dimensions, including: the relationship between CMI and cost/resource use; CMI and hospital efficiency, DRG reforms and hospital performance, and differences across countries and methodological approaches. Because the review included only published studies, the possibility of publication bias cannot be excluded. The overall strength of evidence was assessed based on the results of the methodological quality evaluation.

RESULTS

3.1 Study Characteristics

A total of 10 studies were included in this systematic review, published between 2002 and 2025. The geographical coverage of the studies included international comparative analyses of OECD countries, evaluations of European DRG systems, and empirical assessments of hospital financing and efficiency in countries such as China and Saudi Arabia. These findings indicate that the DRG-based Case-Mix Index (CMI) is widely used not only

within individual national contexts but also in cross-country comparisons, payment reforms, and evaluations of hospital performance.

The included studies demonstrated considerable diversity in terms of research design and analytical focus. These studies encompassed international comparative analyses, empirical investigations examining the relationship between healthcare costs and case-mix, hospital efficiency assessments, policy reviews, and evaluations of the impact of DRG reforms. Therefore, the selected studies did not rely on a single research design but instead approached the topic from multiple analytical perspectives.

The analytical methods employed across the studies also varied. Some studies focused on developing internationally comparable case-mix indices and conducting cross-country comparisons, while others applied statistical analyses to assess hospital cost variation and the effects of risk adjustment beyond the Case-Mix Index. In addition, several studies used case-mix-based models to evaluate hospital efficiency and resource allocation. These findings suggest that DRG-based CMI functions not merely as a descriptive indicator but also as a key analytical measure in assessing hospital efficiency, cost performance, and the impact of payment reforms.

Across most studies, the Case-Mix Index was used as an indicator of hospital complexity, service intensity, resource utilization, or as a benchmark for DRG-based financing systems. Some studies used CMI as a comparative index for international benchmarking, while others examined its relationship with hospital cost variation, payment reforms, resource allocation, and healthcare quality and utilization indicators. Consequently, the role of CMI varied across studies depending on the research objective. In particular, it was applied in several capacities, including efficiency adjustment, complexity measurement, and reimbursement benchmarking. Regarding outcome measures, most studies focused on indicators such as cost per case, variation in hospital expenditures, resource allocation, length of hospital stay, service efficiency, and the impact of payment reforms. In some studies, DRG-based payment systems and the Case-Mix Index were also evaluated alongside quality indicators, service utilization patterns, and post-reform performance changes.

Overall, the ten included studies indicate that the DRG-based Case-Mix Index has been consistently used internationally as a key measure in analyzing hospital efficiency and healthcare financing systems. However, because the studies differed in their objectives, data sources, outcome variables, and operational definitions of the Case-Mix Index, interpretation of the findings requires careful consideration of differences in health system structures, financing models, and case-mix measurement methodologies across countries.

Table 2. Characteristics of the Included Studies

Study title	Year Country /region Study design	Study Scope	Application of CMI/DRG	Primary Outcome Measures
Toward an International Case Mix Index for Comparisons of DRG-Based Health Care Systems	2002; Multiple countries; International comparative study	Cross-country comparison of DRG-based health systems	Developed and compared international CMI	Cost per case, cost per day, cross-country comparison
The impact of DRG-based payment systems	2004; OECD countries;	Analysis of DRG payment and quality	Used international case-mix index	Quality of care, impact of DRG-based payment

on quality of health care in OECD countries	Comparative policy analysis	indicators across countries		
Case mix measures and diagnosis-related groups: opportunities and threats for inpatient dermatology	2005; Germany; Sectoral analysis	Practical application of DRG and case-mix measures	Linked case-mix measures with DRG revenue	DRG, revenue, case-mix measurement
Comparing hospital costs: what is gained by accounting for more than a case-mix index?	2009; Europe; Empirical cost analysis	Comparison of hospital costs	Used CMI for cost adjustment	Hospital costs, additional risk adjustment
Estimation of hospital efficiency—Do different definitions and casemix measures for hospital output affect the results?	2009; Europe; Empirical efficiency analysis	Hospital output definition and efficiency estimation	Used case-mix measures for output adjustment	Hospital efficiency, output definition
Diagnosis-Related Groups in Europe: Moving Towards Transparency, Efficiency and Quality in Hospitals	2011; 12 European countries; Policy review and comparative analysis	Experiences of EuroDRG project countries	Explained DRG systems and case-mix funding	Efficiency, transparency, quality
Diagnosis-Related Group (DRG)-based Case-Mix Funding: The Way Forward for China's Hospital Payment Reform?	2018; China; Policy analysis	Hospital payment reform	DRG-based case-mix funding model	Payment reform, funding mechanism
Efficiency and Resource Allocation in Government Hospitals in Saudi Arabia: A Casemix Index Approach	2023; Saudi Arabia; Empirical efficiency study	Efficiency and resource allocation in public hospitals	Used case-mix index approach	Efficiency, resource allocation
Using Case Mix Index within Diagnosis-Related Groups to Evaluate Variation in Hospitalization Costs at a Large Academic Medical Center	2024; USA; Empirical cost analysis	Cost variation within DRG levels in an academic medical center	Used CMI as a benchmarking indicator within DRGs	Cost variation, benchmarking

3.2 Comparative Analysis of Studies on DRG-Based Case-Mix Index and Hospital Performance

Table 3. Comparative Analysis of Studies on DRG-Based Case-Mix Index and Hospital Performance

Study title	Complexity indicator	Risk adjustment	Payment / funding benchmark	Output adjustment	Тайлбар
Toward an International Case Mix Index for Comparisons of DRG-Based Health Care Systems	Indicates cross-country differences in case complexity	Not used	Used as a financial benchmarking indicator	Not used	CMI was used as a basis for comparing case-mix differences across countries and as a benchmark for healthcare financing.

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The impact of DRG-based payment systems on quality of health care in OECD countries	Reflects hospital case complexity	Used to adjust differences in quality outcomes	Used as a benchmark for DRG-based payment systems	Not used	CMI was applied as a complexity and risk-adjustment measure in explaining the relationship between DRG payments and quality of care.
Case mix measures and diagnosis-related groups: opportunities and threats for inpatient dermatology	Represents patient structure and case complexity	Not used	Linked with DRG revenue and reimbursement mechanisms	Not used	Case-mix measures were used as key indicators of complexity and hospital revenue calculation.
Comparing hospital costs: what is gained by accounting for more than a case-mix index?	Represents hospital case complexity	Used in statistical adjustment for cost variation	Not used	Not used	CMI was identified as a baseline indicator for explaining hospital costs but was insufficient as a standalone measure.
Estimation of hospital efficiency—Do different definitions and casemix measures for hospital output affect the results?	Represents hospital output complexity	Not used	Not used	Used for case-mix-adjusted output measurement	Case-mix measures were used for output adjustment, influencing hospital efficiency scores.
Diagnosis-Related Groups in Europe: Moving Towards Transparency, Efficiency and Quality in Hospitals	Represents complexity of hospital services	Not used	Used as a basis for DRG-based funding and transparency mechanisms	Not used	DRG-based case-mix funding was interpreted as a policy tool linked with transparency and efficiency improvements.
Diagnosis-Related Group (DRG)-based Case-Mix Funding: The Way Forward for China's Hospital Payment Reform?	Indicates hospital workload and case complexity	Not used	Used as a benchmark for funding reform	Not used	CMI served as a key financing indicator in China's DRG-based hospital payment reform.
Efficiency and Resource Allocation in Government Hospitals in Saudi Arabia: A Casemix Index Approach	Represents hospital case complexity	Not used	Used as a financial benchmark for resource allocation	Used in efficiency-adjusted output evaluation	The casemix index approach was used to assess hospital efficiency, resource allocation, and performance.
Using Case Mix Index within Diagnosis-Related Groups to Evaluate Variation in Hospitalization Costs at a Large Academic Medical Center	Indicates complexity differences within DRGs	Used for cost variation adjustment	Used in benchmarking and cost comparison	Not used	CMI was used to identify cost variation and improvement opportunities within DRG-based hospital services.

Interpretation: As shown in Table 3, most of the selected studies used the Case-Mix Index (CMI) as a primary indicator of hospital case complexity. In the majority of studies, CMI was applied as a benchmark for financing and payment mechanisms. Only a limited number of studies employed CMI for purposes such as risk adjustment and output adjustment. Overall, the findings indicate that within DRG-based systems, CMI functions not only as a measure of case complexity but also as a key analytical tool for evaluating hospital costs, efficiency, and resource allocation.

3.3 Main Outcome Variables

Table 4. Comparison of Key Outcome Indicators

Study title	Efficiency outcomes	Cost outcomes	Quality / performance outcomes	Rationale for inclusion
Toward an International Case Mix Index for Comparisons of DRG-Based Health Care Systems	Efficiency not directly quantified using formal models, but inferred through CMI-based cross-system performance comparisons	Cost per case and per day directly estimated using DRG weights	Performance differences interpreted through CMI-weighted comparisons	Selected for demonstrating CMI as a standardized tool for international comparison
The Impact of DRG-Based Payment Systems on Quality of Health Care in OECD Countries	Efficiency not formally modeled (e.g., DEA/SFA), but indirectly addressed through system-level performance effects of DRG reforms	Costs not directly estimated; discussed in relation to payment system changes	Quality of care directly assessed under DRG payment systems	Selected for capturing the quality dimension of DRG-based reforms
Case Mix Measures and Diagnosis-Related Groups: Opportunities and Threats for Inpatient Dermatology	Efficiency not quantitatively measured; implications discussed in terms of DRG/CMI impact on clinical performance	Cost implications discussed conceptually in relation to DRG reimbursement	Performance risks and opportunities interpreted qualitatively	Selected for illustrating specialty-level application and limitations of DRG/CMI
Comparing Hospital Costs: What is Gained by Accounting for More than a Case-Mix Index?	Efficiency not directly measured; inferred through observed cost differentials across hospitals	Hospital cost variation directly estimated beyond CMI adjustments	Performance differences interpreted through cost variation	Selected for demonstrating limitations of CMI as a sole explanatory factor
Estimation of Hospital Efficiency—Do Different Definitions and Casemix Measures for Hospital Output Affect the Results?	Efficiency directly estimated using DEA/SFA models with alternative case-mix specifications	Costs not independently estimated; addressed indirectly through output definitions	Performance effects examined through variation in output measurement	Selected for methodological insights into CMI use in efficiency models
Diagnosis-Related Groups in Europe: Moving Towards Transparency,	Efficiency not directly quantified; discussed at policy	Cost control mechanisms analyzed within	Performance and transparency	Selected for comprehensive policy-

Efficiency and Quality in Hospitals	level in relation to DRG implementation	DRG-based systems	interpreted at system level	level analysis of DRG impacts
Diagnosis-Related Group (DRG)-Based Case-Mix Funding: The Way Forward for China's Hospital Payment Reform?	Efficiency not directly estimated; potential efficiency implications discussed in reform context	Cost implications discussed through DRG-based funding mechanisms	Performance linked to financing reforms at policy level	Selected for representing DRG reform in transitional health systems
Efficiency and Resource Allocation in Government Hospitals in Saudi Arabia: A Casemix Index Approach	Technical efficiency directly estimated using DEA with CMI adjustment	Costs not separately modeled; incorporated as input variables in efficiency estimation	Resource allocation and performance jointly assessed	Selected for directly linking CMI with efficiency and resource allocation
Using Case Mix Index within Diagnosis-Related Groups to Evaluate Variation in Hospitalization Costs at a Large Academic Medical Center	Efficiency not directly modeled; inferred through benchmarking of cost variation	Hospitalization cost variation directly estimated using CMI	Performance differences interpreted through cost-based benchmarking	Selected for empirical evidence linking CMI with cost variation

Outcome variables are classified based on how they were operationalized within each study. In several cases, efficiency was not explicitly quantified using formal models (e.g., DEA or SFA), but was indirectly captured through cost variation, resource use, and performance differentials associated with CMI. This heterogeneity reflects differences in analytical focus rather than omission, and was intentionally retained to capture the multidimensional role of CMI across efficiency, cost, and performance domains.

3.4 Synthesis of Findings

Table 5. Relationship between CMI and Efficiency

Study	Key finding
Estimation of hospital efficiency—Do different definitions and casemix measures for hospital output affect the results?	Changes in casemix measures were associated with changes in hospital efficiency scores.
Efficiency and Resource Allocation in Government Hospitals in Saudi Arabia	The casemix index approach provided a practical method for identifying differences in hospital efficiency.
How DRG Payment Reform Shapes Inpatient Neurological Service Efficiency	DRG reform and increases in CMI were associated with changes in service efficiency.

Based on the evidence presented in the table, the Case-Mix Index (CMI) does not function as a direct measure of hospital efficiency; rather, it serves as a critical adjustment factor necessary for accurate efficiency assessment. In the absence of case-mix adjustment, efficiency scores

may be biased, whereas incorporating CMI enables a more valid comparison of hospital performance by accounting for differences in patient complexity. However, the findings do not demonstrate a consistent or direct relationship between CMI and efficiency. Instead, efficiency outcomes appear to be jointly determined by multiple factors, including the structure of DRG classification systems, payment mechanisms, and the organization of healthcare services.

Table 6. Relationship between CMI and Cost / Resource Use

Study	Key finding
Toward an International Case Mix Index for Comparisons of DRG-Based Health Care Systems	CMI served as a key metric for comparing cost per case and cost per day across countries.
Comparing hospital costs: what is gained by accounting for more than a case-mix index?	CMI alone was insufficient; additional risk adjustment may be necessary.
Using Case Mix Index within Diagnosis-Related Groups to Evaluate Variation in Hospitalization Costs	CMI was useful for explaining cost variation within DRG categories.
Efficiency and Resource Allocation in Government Hospitals in Saudi Arabia	Casemix-based evaluation demonstrated the potential for improving the efficiency of resource allocation.

Based on the evidence presented in the table, the Case-Mix Index (CMI) shows the strongest association with costs and resource utilization, with higher CMI values reflecting greater resource use and higher treatment costs. However, CMI alone is insufficient to fully explain variations in costs, and additional risk adjustment is required. Therefore, CMI functions not only as a foundational measure for evaluating costs and resource use but also as an important policy tool for guiding resource allocation decisions.

Table 7. Relationship between DRG Reform and Hospital Performance

Study	Key finding
The impact of DRG-based payment systems on quality of health care in OECD countries	DRG payment reform was associated with quality indicators; however, its impact varied across countries.
Diagnosis-Related Groups in Europe	The DRG system was designed to promote transparency, efficiency, and quality in hospital services.
DRG-based Case-Mix Funding: The Way Forward for China's Hospital Payment Reform?	DRG-based case-mix funding was concluded to be a more efficient reform mechanism compared with fee-for-service (FFS).
How DRG Payment Reform Shapes Inpatient Neurological Service Efficiency	Following the reform, changes were observed in CMI, DRG weights, average length of stay (ALOS), and inpatient costs.

Interpretation: The findings from the included studies indicate that reforms in DRG-based payment systems are closely associated with hospital performance, efficiency, and quality indicators. The introduction of DRG systems has been linked to improvements in financial transparency, service efficiency, and more efficient resource utilization. Several studies also reported changes in key indicators such as CMI, DRG weights, average length of stay (ALOS), and hospital costs following the implementation of DRG reforms, suggesting that payment system reforms may influence hospital operational performance. However, the magnitude and nature of these effects appear to vary across countries depending on the structure of the healthcare system and the level of policy implementation.

Table 8. Differences by Country and Methodology

Comparison dimension	Observed differences
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Country	Studies conducted in OECD and European countries mainly focused on policy and system-level analysis, whereas studies from Saudi Arabia and China were more concentrated on empirical analyses and reform implementation at the hospital level.
Methodology	Some studies employed policy reviews, while others used empirical cost analyses or evaluations of efficiency and resource allocation.
Use of CMI	In some studies, CMI was used as a complexity indicator; in others, it served as a funding benchmark or as a measure for output adjustment.
Outcomes	Some studies focused on cost outcomes, others on efficiency, while some examined quality and performance indicators.

Interpretation: The reviewed studies demonstrate that research conducted in OECD and European countries predominantly focuses on policy and financing system analyses. In contrast, studies from countries such as Saudi Arabia and China more frequently emphasize empirical analyses at the hospital level. Methodologically, the studies vary considerably: some employ policy reviews, others conduct quantitative analyses of costs and resource utilization, while some focus on evaluations of efficiency and resource allocation. Furthermore, the role of CMI differs across studies. In certain cases, it is used as a complexity indicator reflecting hospital case severity; in others, it serves as a financial benchmark or as a tool for output adjustment. These findings suggest that CMI is a multidimensional indicator with diverse applications in evaluating hospital performance, costs, and quality of care.

DISCUSSION

The findings of this systematic review indicate that the DRG-based Case-Mix Index has been widely used to explain hospital efficiency, costs, and resource allocation. However, its application varies depending on the country, research objectives, and methodological approaches. In most studies, CMI was used as a primary indicator of service complexity, resource demand, and the baseline level of hospital financing. In other studies, it was applied as an output adjustment factor in efficiency analysis, a risk-adjustment variable, or a benchmark for funding mechanisms. These findings suggest that CMI has evolved beyond a purely technical indicator and has become an important policy tool for hospital financing and performance management.

Overall, higher CMI values generally reflected more complex and resource-intensive hospital services, but this did not necessarily imply higher efficiency. In some studies, the use of case-mix adjustment enabled more accurate comparisons of hospital efficiency across institutions. In others, researchers emphasized that additional patient-level and hospital-level adjustments were required beyond CMI. Therefore, when using CMI to evaluate hospital efficiency, it should not be interpreted in isolation but rather in conjunction with factors such as the structure of the DRG classification system, coding quality, financing rules, definitions of hospital output, and quality indicators.

The reviewed studies also suggest that DRG-based and case-mix-based funding mechanisms can improve cost transparency and support more efficient resource allocation. However, excessive reliance on CMI within financing systems may create unintended incentives, including increased coding intensity, risks of upcoding, shifts toward higher-weighted DRG categories, or reductions in length of stay that may negatively affect the quality of care. Consequently, although DRG-based CMI represents an important mechanism for improving efficiency, it should be implemented alongside quality monitoring, coding audits, and outcome-based evaluation to prevent potential unintended consequences.

Limitations

The ten included studies differed in research design, data sources, outcome measures, and operational definitions of CMI, limiting direct quantitative comparison. Most studies were based on data from high-income countries with established DRG systems, which restricts the generalizability of the findings to low- and middle-income settings, particularly referral-level hospitals. In addition, although CMI was widely used as a complexity indicator and funding benchmark, relatively few studies examined its direct relationship with technical efficiency, cost efficiency, or productivity using panel or longitudinal data. Quality outcomes such as mortality, readmission, and patient-centered indicators were also rarely assessed. Consequently, the overall impact of CMI-based financing on healthcare quality remains unclear.

Significance of the Study

Within DRG-based financing systems, the Case-Mix Index (CMI) has emerged as a key metric that integrates patient complexity and resource utilization, and is widely used in evaluating hospital performance, costs, and financing. However, despite its multifaceted applications, there is a relative lack of systematic synthesis linking CMI to hospital efficiency, and a coherent methodological framework remains underdeveloped, representing an important research gap. This systematic review contributes to both theoretical and empirical research by systematically examining the application of DRG-based CMI in relation to hospital efficiency, resource allocation, and financing evaluation, while identifying current research trends and methodological heterogeneity. In particular, the study highlights the methodological significance of CMI not only as a measure of patient complexity, but also as a tool for performance weighting, risk adjustment, cost standardization, and efficiency analysis (e.g., Data Envelopment Analysis, DEA).

From a practical and policy perspective, this study provides evidence-based insights for using CMI to enable fair comparisons across hospitals, align financing with actual service burden, optimize resource planning, and improve cost efficiency. Furthermore, for countries implementing DRG-based payment reforms—particularly Mongolia—the findings offer important policy-relevant evidence for hospital resource management, tariff setting, and strategic planning. Overall, this study establishes an integrated analytical framework that links case-mix complexity, resource utilization, and hospital efficiency, thereby contributing to theory, methodology, and policy in enhancing health system performance.

CONCLUSION

The findings indicate that the Case-Mix Index (CMI) does not function as an independent measure that directly determines hospital efficiency; rather, it serves as a critical adjustment factor necessary for accurately assessing efficiency. In particular, the observed variation in efficiency scores in response to changes in case-mix measures and output definitions suggests that efficiency evaluation is highly sensitive to differences in patient complexity. Therefore, comparing hospital efficiency without case-mix adjustment may lead to biased conclusions, whereas the incorporation of CMI enables a more valid interpretation of performance differences. However, the overall evidence does not support a stable or direct relationship between CMI and efficiency, indicating that efficiency is jointly influenced by multiple factors, including the structure of DRG classification systems, payment mechanisms, and the organization of healthcare services.

On the other hand, CMI demonstrates the strongest and most consistent association with costs and resource utilization. Across the majority of studies, CMI has been directly applied to explain variations in cost per case, hospitalization costs, and service burden, with higher CMI values reflecting greater resource use and higher treatment costs. Nevertheless, several studies suggest that CMI alone is insufficient to fully account for cost variation, highlighting the need to incorporate additional factors such as risk adjustment, patient mix, and treatment characteristics. This indicates that CMI is a necessary but not sufficient condition for cost evaluation.

Furthermore, CMI-based assessment has been shown to play an important role in optimizing resource allocation. Evidence from studies on DRG-based funding and payment reforms suggests that CMI is increasingly used as a benchmark for hospital financing, a tool for guiding resource distribution, and a mechanism for performance evaluation. Therefore, CMI should be understood not merely as a technical measurement indicator, but as an integrated analytical bridge linking patient complexity, costs, resource utilization, and hospital performance within health system evaluation.

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