

Business Intelligence Frameworks for Improving Operational Efficiency and Patient Outcomes in Rural United States Hospital Systems

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Publication Date: 2026/10/05

Abstract: In the United States, rural hospitals are closing at a rate that now exceeds that of new hospital construction, resulting in an increased distance to emergency, maternity, and inpatient hospital services for millions of Americans annually. This review article explores the possibility of building a business intelligence (BI) framework, including a set of dashboards, key performance indicators (KPIs) and visualization tools, to enhance operational efficiency and patient outcomes within an organization that operates in a resource-limited setting within rural healthcare environments. The review summarizes the findings from peer-reviewed literature, staffing forecasts from various federal agencies, cost-report data from hospitals, and vendor pricing analyses published through 2026, providing a synthesis of evidence on rural-urban differences in health information technology adoption, financial distress indicators most likely to signal health care facility closure, and operational metrics most important for rural administrators to monitor in real time. A multi-layer BI framework is introduced, which consists of four layers: data sourcing, integration and governance, analytics, visualization and decision-action, as well as a three-level hierarchy of KPIs, distinguishing strategic, tactical, and operational KPIs. The review also compares commercial and open-source BI tool categories based on costs and capabilities, identifies technical, financial, workforce and cultural barriers to adoption, and recommends a phased, eighteen-month implementation roadmap that allows critical access and other rural hospitals to focus on tracking their metrics first, based on limited capital and staffing resources. The review concludes that the most realistic path for rural hospitals to catch up with their urban counterparts in their ability to address the analytics gap and transform operational data into enduring improvements in efficiency, financial stability and patient safety is a disciplined, tiered approach for this type of adoption rather than an enterprise-wide rollout.

Keywords: Business Intelligence; Rural Hospitals; Key Performance Indicators; Dashboards; Critical Access Hospitals; Healthcare Analytics; Operational Efficiency; Patient Outcomes.

How to Cite: Sesi Mensah Gidisu; Millicent Naa Oye Boadu; Joseph Kobi (2026) Business Intelligence Frameworks for Improving Operational Efficiency and Patient Outcomes in Rural United States Hospital Systems. *International Journal of Innovative Science and Research Technology*, 11(9), 2753-2780. <https://doi.org/10.38124/ijisrt/26sep1243>

I. INTRODUCTION

➤ The Widening Access Crisis Facing Rural Hospital Systems

Rural hospitals occupy a structurally precarious position within the broader United States healthcare system, and the gap between rural and urban facility viability has widened rather than narrowed in recent years. Closures of rural hospitals exceeded openings between 2017 and 2023, with sixty-one rural facilities closing against only eleven that opened, a net reduction of fifty hospitals nationwide (U.S. Department of Health and Human Services, Office of the

Assistant Secretary for Planning and Evaluation [ASPE], 2026). Since 2010, roughly eight percent of rural hospitals have closed or converted to outpatient-only status, compared with only 3.5 percent of urban hospitals over the same period (ASPE, 2026; U.S. Department of Agriculture, Economic Research Service [USDA ERS], 2025).

The weak economy that has been the source of these closures is growing worse, not better. Since the end of pandemic era federal support, virtually one-third of rural hospitals reported a loss over the last 2 years, 2024 and 2025, and more than forty percent of rural hospitals nationwide

have reported to lose money on patient services (Becker's Hospital Review, 2026). In mid-2026, nearly seven hundred rural hospitals were deemed at risk of closure, and about three hundred were deemed to be at immediate risk (Becker's Hospital Review, 2026; Journal of Urgent Care Medicine, 2025). Over the last decade alone, over one hundred rural hospitals have closed and 53 since 2023 have shuttered inpatient facilities to meet the stricter requirements for the newer Rural Emergency Hospital (REH) designation and federal reimbursements (Becker's Hospital Review, 2026).

The impact of closure is felt far and wide, beyond a facility's balance sheet. Rural hospitals are often the largest employers in the surrounding area and rural hospital closures are linked to increased travel time to hospitals, poorer maternal and infant health, and economic impacts on the surrounding community (Boston University School of Public Health, 2025; Chartis Center for Rural Health, 2026). Nearly one-quarter of all rural hospitals (293 facilities) completely ceased offering obstetric services between 2011 and 2023, increasing the size of what researchers now call "rural maternity care deserts" (Chartis Center for Rural Health, 2026).

➤ *Business Intelligence as an Underused Lever for Rural Stability*

Business intelligence (BI), defined as the overlay of dashboard reporting, KPI tracking and data visualization that transforms raw operational data into actionable intelligence, is a common practice among well-resourced urban health systems, but seldom seen in rural facilities (Binariiks, 2026; SPD Technology, 2026). In large academic and community hospitals, near real-time tracking of surgical case cost, operating-room turnover, and the number of patients in the ED has been implemented routinely, and has resulted in measurable savings in both the number of hours patients spend in the ED and the variation in cost per case (Leveraging Business Intelligence Dashboards for Real-Time Clinical and Operational Transformation in Healthcare Enterprises, 2025).

Although empirical evidence of the impact of BI on hospital performance is largely from larger systems, the magnitude of the potential benefits is clearly suggested. Secondary analyses of BI implementations report up to thirty-five percent wait-time reduction, readmission-rate reductions near twenty percent and staffing-utilization improvements near twenty-five percent in the health systems studied (Data-Driven Healthcare: The Role of Business Intelligence Tools in Optimizing Clinical and Operational Performance, 2025). In another case study, a pediatric hospital implemented an integrated BI system that led to a 30% decrease in readmissions and a 20% increase in the management of chronic diseases after its deployment (Garba et al., as cited in The Role of Business Intelligence Tools in Improving Healthcare Patient Outcomes and Operations, 2024).

But rural hospitals have not been as quick to embrace even the more basic layers of health IT, much less the more sophisticated analytics layers built on top of them. Rural hospitals had fewer health-information-exchange functionalities (Yan et al., 2025) and fewer patient-

engagement functionalities in 2023 compared to their urban counterparts, and were much less likely to report using any health-information-exchange capability at all. A related national fifteen-year study revealed that while adoption of simple electronic health records (EHRs) is nearly ubiquitous, rural hospitals lag four to fifteen percentage points behind urban hospitals in measures of advanced EHR capabilities, including social-determinants-of-health data capture, public-health reporting, and interoperability (The Digital Divide in Adoption and Advanced Use of Electronic Health Records Among US Hospitals, 2026).

➤ *Purpose, Scope, and Contribution of This Review*

The three questions that the following review article will attempt to answer are intimately connected with each other, and comparatively few times have been discussed together in the rural health literature. First, what metrics – such as bed utilization, average length of stay, emergency department throughput, etc. – are most important for rural hospital administrators to track when analytic resources are limited? Second, the feasibility of adapting second-hand or free business intelligence tools to meet the technical and financial requirements of rural facilities. Third, what technical, financial and cultural challenges are consistently limiting rural hospitals from implementing a data-driven decision-making process, and how these obstacles can be overcome in a systematic fashion, using a staged implementation plan.

The rest of the article follows. In Section 2, you will find the definitions of rural hospitals and explore the financial and demographic challenges that make BI adoption more difficult and critical in rural areas. The methodology for the review is described in Section 3. Sections 4-7 build up a five-layer BI framework, list the most relevant operational and clinical KPIs for rural administrators and compare the two categories of commercial and open-source tools. In sections 8 and 9, the barriers to adoption, and examples of good practice patterns are explored. Section 10 outlines the suggested roadmap for the implementation of the proposed plan, while Sections 11-13 address policy implications, direction for future research, and conclusions. The review is based on actual operational and financial statistics from federal agencies, peer reviewed publications of journals of research groups within the hospital sector and makes a definite distinction between empirical data and illustrative or conceptual data that is added to support the framework.

II. BACKGROUND AND SIGNIFICANCE

➤ *Defining Rural Hospitals and the Critical Access Designation*

Rural hospitals are typically defined as community, nonfederal, acute care hospitals in areas outside a metropolitan statistical area (MSA), though various federal programs have different definitions of the rural-urban commuting area (RUCA) (American Hospital Association [AHA], 2025). Within the U.S. in 2023, there were 5,112 community hospitals across the country, with 1,796 being in rural areas, representing about one-third of community hospitals (AHA, 2025), yet receiving a very small proportion

of the nation's population. Mid-2024 estimates show that about fourteen percent of the U.S. population (approximately forty-six million) reside in non-urban areas. (ASPE, 2026).

Rural hospitals are also highly underrepresented: 66 percent of rural community hospitals have 50 or fewer staffed beds, and a substantial proportion are designated as Critical Access Hospitals (CAHs) by the federal government, a designation that was established to give small rural hospitals a stabilizing mechanism through cost-based reimbursement for Medicare services (AHA, 2025). Nearly two-thirds of all rural hospitals in the country were critical access hospitals (CAHs) in 2023, and CAHs have unique performance benchmarking, with the Critical Access Hospital Measurement and Performance Assessment System, a tool developed by the Flex Monitoring Teams for comparing CAH financial and quality indicators to national benchmarks (Malone et al., 2025; Yan et al., 2025).

➤ *Financial and Demographic Pressures on Rural Facilities*

Low patient numbers, an unfriendly distribution of payers, high fixed costs, and geographic isolation from the referral system all contribute to financial fragility of rural hospitals. A recent study on cost structure identified a systematic relationship between the ability to adapt to a decline in patient volume and hospitals' fixed-to-total cost ratio, with hospitals with higher ratios being significantly more vulnerable to financial distress and closure (Karim et al., 2026). Factors across several studies that have contributed to the decline of rural hospitals are: smaller facilities, lower bed occupancy, and local economies that are more sensitive to the loss of a major local employer, which can have a significant impact on a rural hospital's insured patient population (USDA ERS, 2025).

Some of the most systematically done predictive modeling research, available on the topic of financial indicators predicting distress, comes from the North Carolina Rural Health Research and Policy Analysis Center. An updated Financial Distress Index model was able to meaningfully separate high-risk from low-risk rural hospitals about two years prior to financial distress, with an area under the receiver operating characteristic curve of 0.87, based on more than fourteen thousand hospital-year observations from 2,311 rural hospitals from 2013 to 2019 (Malone et al., 2025). The four domains are financial performance, government reimbursement structure, organizational characteristics (e.g., ownership and system affiliation), and market characteristics (e.g., distance to the nearest large hospital) all closely align with the KPI categories that a rural hospital BI dashboard should include (Malone et al., 2025; Holmes et al., 2017).

Financial pressures are exacerbated by a shortage of workers. The registered nurse shortage rates are expected to be significantly larger in nonmetro counties than in metro counties over the next decade, with 24 percent of nonmetro counties projected to have an RN shortage by 2028, compared with five percent of metro counties, 18 percent in nonmetro counties by 2033 compared with four percent in metro counties, and 11 percent in nonmetro counties compared with two percent in metro counties by 2038 (Rural Health

Information Hub, 2026, based on Health Resources and Services Administration [HRSA] Bureau of Health Workforce projections). Over 60% of federally designated Health Professional Shortage Areas are located in rural or partially rural areas, while the average cost to replace a single RN who leaves the profession ranges from about \$45,100 to \$67,500, and the time to hire can range from fifty-nine days to one hundred nine days (Nurse.org, 2025; National Rural Health Association, 2024).

➤ *The Technology Gap Between Rural and Urban Hospitals*

While many rural hospitals have embraced a basic electronic health record system, more extensive HIT capability gaps remain. According to the repeated cross-sectional analysis of the American Hospital Association's (AHA) 2008–2020 survey data, comprehensive EHR capability grew from 2 percent of hospitals in 2008 to 75 percent in 2020, while adoption of certified EHR (CEHR) technology was approaching universal adoption, but the digital divide between urban and rural hospitals widened by four to 15 percentage points across advanced functions such as interoperability, public health reporting, and data collection on social determinants of health as of 2023 (The Digital Divide in Adoption and Advanced Use of Electronic Health Records Among US Hospitals, 2026). Limited capital to invest in technology, restricted broadband infrastructure, and lack of informatics expertise are identified as barriers in this literature and are as applicable as they are to BI and analytics adoption (The Digital Divide in Adoption and Advanced Use of Electronic Health Records Among US Hospitals, 2026; Barriers to Electronic Health Record Adoption: A Systematic Literature Review, 2016).

This gap is significant as BI capability is typically built on top of existing HIT infrastructure rather than separate. A KPI dashboard is not the easy choice for a hospital where the data pipelines are not reliable, and the data warehouse is not stable. Older, sicker, and more geographically scattered patients, and fewer resources and technical teams at rural hospitals mean they are likely to reap greater benefits from capabilities that they have been slowest to implement (The Digital Divide in Adoption and Advanced Use of Electronic Health Records Among US Hospitals, 2026).

➤ *The Scale, Distribution, and Economic Footprint of Rural Hospitals*

The large size of the rural hospital sector, and its disproportionate economic contribution to clinical care compared to its clinical footprint, accounts for many of the consequences of the technology and workforce gaps that have been described above and are not limited to a single hospital's balance sheet. In 2023, there were 5,112 community hospitals in the country, of which 1,796 were located in rural areas, or a third of the country's community hospital infrastructure, operating under the same staffing, capital and technology constraints described in this section (AHA, 2025). Of those facilities, 66% have 50 beds or fewer, a scale significantly lower than the typical scale of most commercial BI platforms (AHA, 2025).

In addition to providing direct health care, rural hospitals serve as key employers in the community and provide an economic boost to the community, creating jobs for both clinical and non-clinical employees, buying goods and services from local vendors, and generating local and state tax revenues that many rural counties are heavily reliant

upon (AHA, 2025). This economic interdependence accounts for the ripple effect that a rural hospital's financial difficulty has on the surrounding local economy, and the closures cited in Section 1.1, well before a hospital's inpatient beds are formally decertified, supports the need for the early-warning capability in analytics proposed in Sections 4-6.

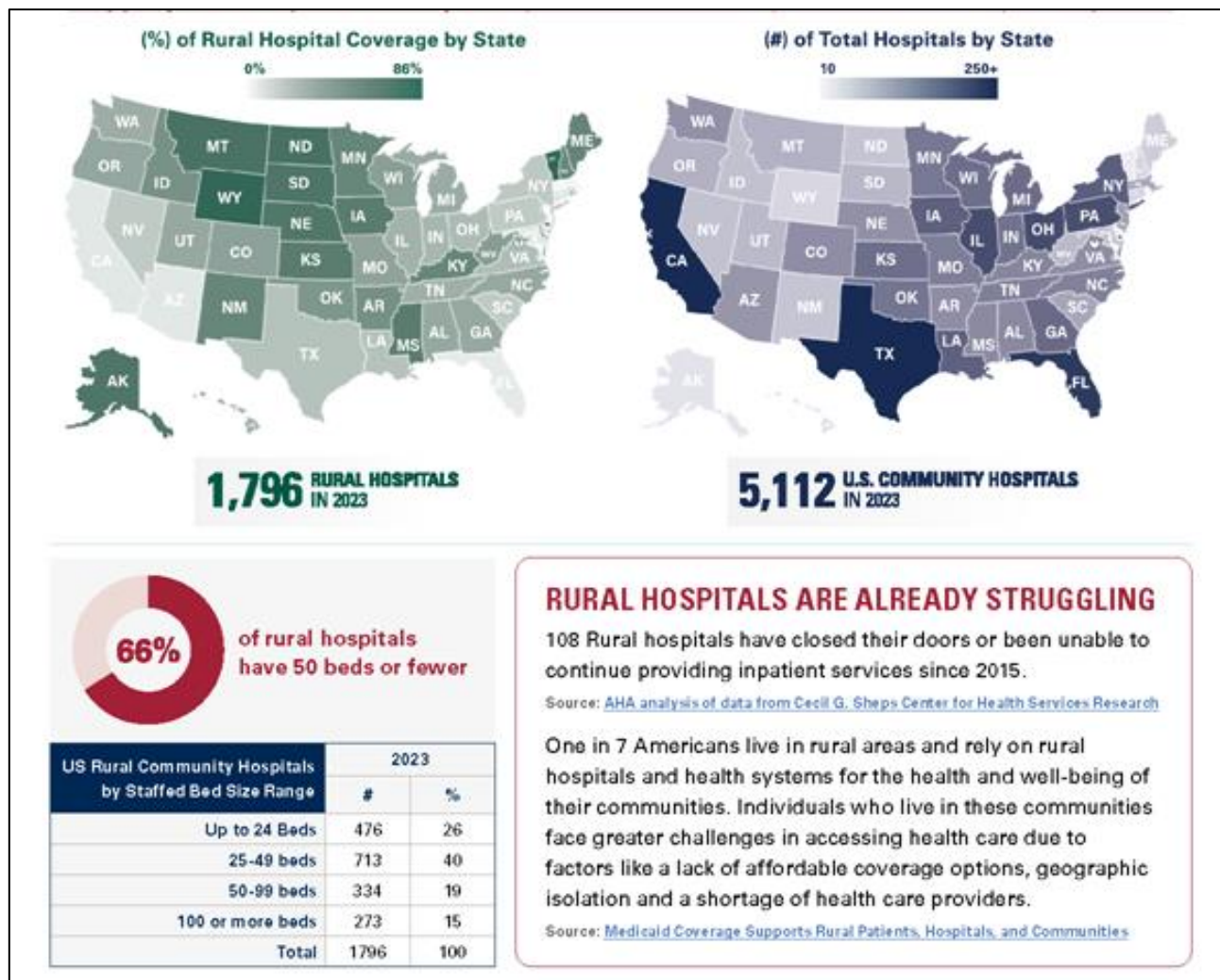


Fig 1 Rural Hospital Distribution, Bed-Size Profile, and Economic Footprint Across the United States, 2023
(Source: American Hospital Association, 2025).

Rural hospital coverage differs significantly by state, both in the percentage of rural hospitals within a state and in the absolute number of rural hospitals in a state that serve rural residents, and this geographic disparity can mean the adoption barriers described in Section 8 will impact a sparsely populated Mountain West state more strongly than a remote rural county within commuting distance of a metropolitan referral center (AHA, 2025). This state-level information is a helpful addition to the national closure and financial-risk numbers listed in Figure 2 and is intended to highlight that a policy level that is based on national averages might not be a good fit for the coverage gaps of any particular state.

As reported in the same source, one hundred eight rural hospitals or health systems closed their doors or ended their inpatient services since 2015, and approximately one in seven Americans rely on a rural hospital or health system for their healthcare—showing that the closures documented across Section 1 are a real risk to healthcare access for tens of millions of Americans living in rural communities (AHA, 2025). Along with the bed-size distribution shown above, these numbers help substantiate the main idea of this review: A BI framework designed to support the small, thinly-staffed and undercapitalized at-risk facility must be scaled down from enterprise assumptions, not adapted from them; this idea is discussed in the five-layer framework developed in Section 4.

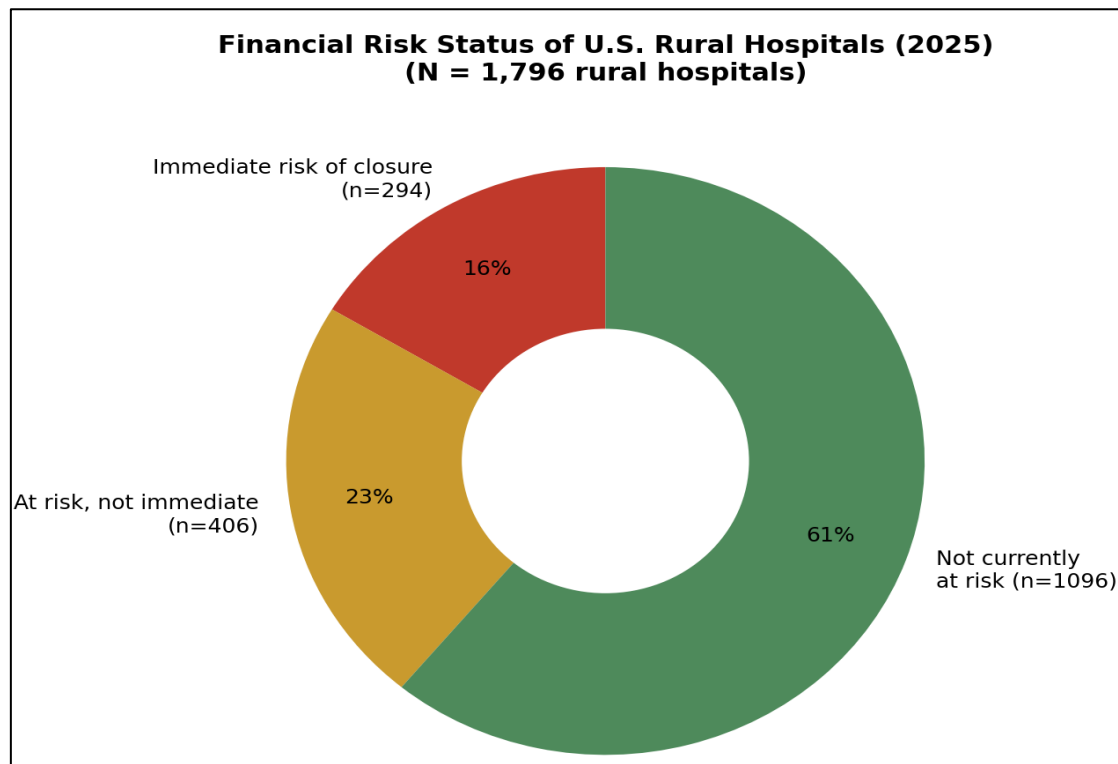


Fig 2 Financial Risk Status of U.S. Rural Hospitals, 2025
(Source: Becker's Hospital Review, 2026, citing Center for Healthcare Quality and Payment Reform data).

Figure 2 breaks down the rural hospital sector into separate financial risk categories as opposed to all hospitals in the sector being classified as at risk for closure and all hospitals being classified as at risk for closure in the long-run. Figure 2 further divides the rural hospital sector into individual categories of financial risk and separates hospitals at immediate risk from closure from the larger group that is deemed to be at risk over a longer period of time. About 700 rural hospitals were identified as being at risk of closure by mid-2026, with approximately 300 hospitals at immediate risk; the distinction is important for policy and institutional planning, as the two groups have different timelines for intervention (Becker's Hospital Review, 2026; Journal of Urgent Care Medicine, 2025).

The separation in Figure 2 between immediate and long-term risk implies design implications for the later-introduced BI framework: A hospital in immediate risk status does not have much time to implement the complete five-layer architecture of Section 4 but has to focus on implementing the fastest-to-deploy financial early-warning indicators of Section 2.2 before having to make more urgent triage decisions, and should choose the former, over the more comprehensive but slower-to-implement analytics and visualization layers (Malone et al., 2025).

III. METHODOLOGY

➤ Review Design and Literature Search Strategy

The narrative-synthesis design was used in this review as it was an emerging topic that crosses the health services research and health informatics/business analytics fields, the latter of which are not necessarily searched together. A

systematic search was performed in PubMed, Web of Science, and general academic and gray literature to find peer-reviewed research, federal reports, and hospital-sector research addressing three related areas: (1) rural hospital financial and operational performance, (2) adoption of business intelligence and dashboard in healthcare, and (3) gaps in health information technology adoption between rural and urban hospitals. The search terms employed were the same as those used in previous extensive studies of hospital cooling systems and building systems that create search strings from topic and outcome terms such as business intelligence, dashboard, KPI, financial distress, length of stay, and ED throughput (Cai & Gou, 2026).

Sources that stated a quantitative operational, financial, or workforce measure of United States rural or critical access hospitals; described an implementation of a business intelligence or dashboard in a healthcare setting; or defined standard measures or benchmarks for a KPI referenced elsewhere in this review were retained. Sources that did not provide a methodological framework—such as a taxonomy for KPIs or a protocol for designing a dashboard—applicable to the rural United States context were excluded unless they expressed a vision of the rural healthcare system outside the United States.

➤ Data Synthesis and Framework Development Approach

As no single published study provides an end-to-end business intelligence framework specifically designed for rural hospitals in the United States, this review does not present any single primary study, but rather integrates aspects of three different sets of literature. Definitions for operational and financial KPIs were based on health services literature on

financial distress and emergency department throughput in rural areas (Annals of Emergency Medicine, 2023; Malone et al., 2025). Drawing on published literature of healthcare BI dashboards and enterprise BI design principles (Dashboards in Health Care Settings: Protocol for a Scoping Review, 2022; Binariks, 2026), BI architecture and layering concepts were identified. Current analysis of vendor pricing (as of 2025 and 2026) was used to compare costs, and cross-referenced with other independent pricing comparison sources to minimize the risk of using a vendor's marketing messages as gospel (Power BI Consulting, 2026, UseDataBrain, 2026, Explo, 2025).

The BI framework and the three-tiered hierarchy of KPIs, along with a staged implementation plan presented in Sections 4, 5 and 10 respectively are the original synthesis developed for this review, and are not a straightforward replication of any one existing model. Figures of financial and workforce trends were built based on the aggregate figures from the sources cited; the proposed financial architecture for the BI, the proposed KPI hierarchy, and the proposed timeline for implementation are original conceptual

figures which have been developed as part of the framework and are labeled accordingly throughout.

➤ *Limitations of the Review Methodology*

The results and conclusions that follow were restricted by a number of limitations. First, there are few published, peer-reviewed studies evaluating BI dashboard implementations specifically in rural or critical access hospitals, and most of the quantitative evidence of BI's impact on operation is collected from larger, more well-resourced health systems; this benefit may not necessarily be replicated at a twenty-five-bed critical access hospital with one part-time analyst. Second, the figures used by vendors to price commercial BI platforms are constantly updated, and even differences in contract terms can alter the price, so it is best to view the cost comparisons in Section 7 as illustrative of relative order-of-magnitude differences and not as current, negotiable list prices. Third, financial and workforce data is collected at the national level for rural hospitals, which hides variation by hospital, which may be a critical issue in determining the viability of a given rural hospital's BI program.

Table 1 The literature Search Terms Used to Identify Sources for This Review.

No.	Search Domain	Search Terms Combined with AND/OR Operators
1	Rural facility scope	"rural hospital" OR "critical access hospital" OR "rural health system" OR "rural emergency hospital"
2	Financial performance	"financial distress" OR "operating margin" OR "hospital closure" OR "cost report" OR "payer mix"
3	Business intelligence	"business intelligence" OR "dashboard" OR "data visualization" OR "analytics platform" OR "key performance indicator"
4	Operational metrics	"bed occupancy" OR "length of stay" OR "emergency department throughput" OR "boarding time" OR "staffing ratio"
5	Technology adoption	"electronic health record adoption" OR "health information technology" OR "interoperability" OR "telehealth adoption"

Using the Boolean operators, the search domains outlined in Table 1 were merged so that sources examining rural hospital viability, business intelligence adoption, and operational metrics could all be accessed from a single structured search, instead of three separate literature searches. This combined-term approach, which more closely mirrors previous comprehensive reviews that combine topic and outcome term together (Cai & Gou, 2026), is implemented because of the cross-disciplinary nature of the topic; a source that focused solely on financial distress in rural hospitals was kept if the source also provided a benchmark or indicator that could be directly applied to the framework developed in Section 4.

The five search domains in Table 1 are used directly in the following structure of the review, which covers the access-crisis literature (Section 1); the adoption-gap literature (Section 2); the business intelligence literature (Section 4); the operational metrics literature (Section 5); and the KPI and dashboard-design literature (Section 6). This coincidence of the focus of the search and the structure of the review is consciously chosen, and explained in more detail as a methodological limitation in Section 3.3, because a search strategy that focuses on five discrete domains is going to favour sources that already operationalize or measure rural

hospital performance in operational or financial terms over those using a different disciplinary vocabulary.

IV. CORE COMPONENTS OF A RURAL HOSPITAL BUSINESS INTELLIGENCE FRAMEWORK

Rural hospitals do not fail at business intelligence due to lack of ambition – they fail because they try to create an enterprise-level analytics program in a single stroke. The five-layer framework presented in this review below and summarized in Table 2, breaks the problem down into layers that can be achieved sequentially and independently, so a small hospital can move towards full capability at each layer and move on to the next before it ends up buying a dashboard product on top of unreliable or disconnected source data.

➤ *The Data Source Layer*

The operational systems that generate operational data on which any BI framework is built are the electronic health record and its admission-discharge-transfer feed, the practice management and scheduling system, the payroll system, the human resource system, the revenue cycle system, and the CMS Healthcare Cost Report Information System (HCRIS) feed that rural hospitals submit annually and that researchers

use to calculate standardized financial benchmarks (Chartis Center for Rural Health, 2026; Malone et al., 2025). The greatest obstacle that a rural hospital will face at this level is not data scarcity, but rather having data that resides in various systems, some of which may still be using manual spreadsheet exports as a data delivery method instead of automated feeds, consistent with reported rural hospitals that experience lower rates of health-information-exchange capability than their urban counterparts (Yan et al., 2025).

In a realistic data-source inventory, the hospital has an EHR platform (usually a vendor product designed for the community or critical access hospital vended, not a large enterprise system), a scheduling and staffing system that is separate from the EHR platform, a standalone billing or revenue-cycle platform, and the hospital's own cost-report submissions. CAHs are already required to submit cost reports to Medicare and CAHMPAS benchmarking reports, meaning these are existing data sources where the standardized fields are already being collected and audited, which is a relatively low cost starting point for the development of BI (Malone et al, 2025).

➤ *The Data Integration and Governance Layer*

Most rural BI projects either take off or fail to take off in the integration layer. This layer is reliant on extract-transform-load (ETL) pipelines or – increasingly – lightweight API connectors, which extract data from each of the source systems to the single standardised repository on a regular basis, and on rules for master data (e.g. a patient discharged from the emergency department is always counted in the scheduling system, in the billing system and in the clinical system). At this level, HIPAA-compliant storage and role-based access control needs to be put in place before constructing any dashboard on top of it, as a poorly governed data warehouse can introduce novel privacy exposure as it enhances operational visibility (Barriers to Electronic Health Record Adoption: A Systematic Literature Review, 2016).

Layered governance also involves having a single, hospital-wide definition for each metric before it is displayed anywhere—which is often not performed in fast-moving BI rollouts. When the leadership in nursing and finance reports different numbers for the length of stay on the dashboard, for example, including observation patients as nursing or excluding them as finance, these numbers do not add up and erode trust in the system as a whole, and this is a pattern that is widely observed in the literature on BI adoption in the healthcare industry, which highlights the importance of trust in the quality of the data in a dashboard as the key to whether nurses will actually use it once it is created (Healthcare Business Intelligence: Tools to Improve Patient Outcomes, 2024).

➤ *The Analytics Layer*

The analytics layer puts the information from the integrated data to work by deriving calculated indicators, moving from what happened to why it happened, and ultimately to what might happen next. The practical starting point for most rural hospitals is descriptive KPI calculation – being the ability to calculate their KPIs (e.g. bed occupancy,

average length of stay, staffing ratios, etc.) automatically on a set schedule, instead of manually at the end of each month on a spreadsheet. For more advanced rural systems, a diagnostic drill down capability can be added on top, so that a rural administrator could click from a facility-level readmission rate to the specific unit, shift or specific diagnosis category contributing to the trend.

Even though predictive analytics is further down the maturity curve, it is soon becoming attainable for smaller systems. However, academic studies of the use of accelerated failure time (AFT) models in length of stay for emergency department (ED) visits have shown that patient and operations level covariates can be of value in predicting the duration of individual visits, which in principle, could be used to inform staffing and diversion decisions at a rural ED in near real-time (Predicting Length of Stay Among Patients Discharged From the Emergency Department, 2017). The rural hospital financial distress models described in Section 2.2 are a fairly sophisticated example of predictive analytics applied specifically to the viability of rural hospitals, and researchers have explicitly requested that these models be "operationalized" into continually updated and real time monitoring tools, not just static, academic exercises (An Updated Model of Rural Hospital Financial Distress, 2025).

➤ *The Visualization, Governance, and Decision-Action Layers*

The visualization layer is the layer of a BI system that can be seen most clearly and is often confused as being the entire BI system. Trend lines, peer benchmarks, and color-coded status indicators make performance immediately interpretable and role specific views, an executive summary, a nursing unit bed board, an emergency department flow board, and a finance and revenue-cycle view ensure that each user has access only to the metrics that impact their decision (Arcadia, 2026; Dashboards in Health Care Settings: Protocol for a Scoping Review, 2022). Inclusion of dashboards within a clinical and administrative workflows, rather than the need to launch a new application, has been recognized as a critical factor to BI uptake in a healthcare environment in general (Healthcare Business Intelligence: Tools to Improve Patient Outcomes, 2024).

The last step in the framework; decision and action, is easy to forget but is where this value comes to fruition. Without a defined escalation pathway, extra per diem staffing, a modified admission threshold, and a transfer protocol attached when the nurse-to-patient ratio falls below a specified threshold, a dashboard that reports an accurate, real-time ratio provides no operational advantage. The connection is documented in case evidence from a community hospital surgical services dashboard: When case-level cost data was correlated with a standing governance meeting in which surgical personnel and perioperative leaders reviewed the data together, the twenty-two percent cost difference between similar surgical cases came to light that could only be acted upon when the groups reviewed the data together (Leveraging Business Intelligence Dashboards for Real-Time Clinical and Operational Transformation in Healthcare Enterprises, 2025).

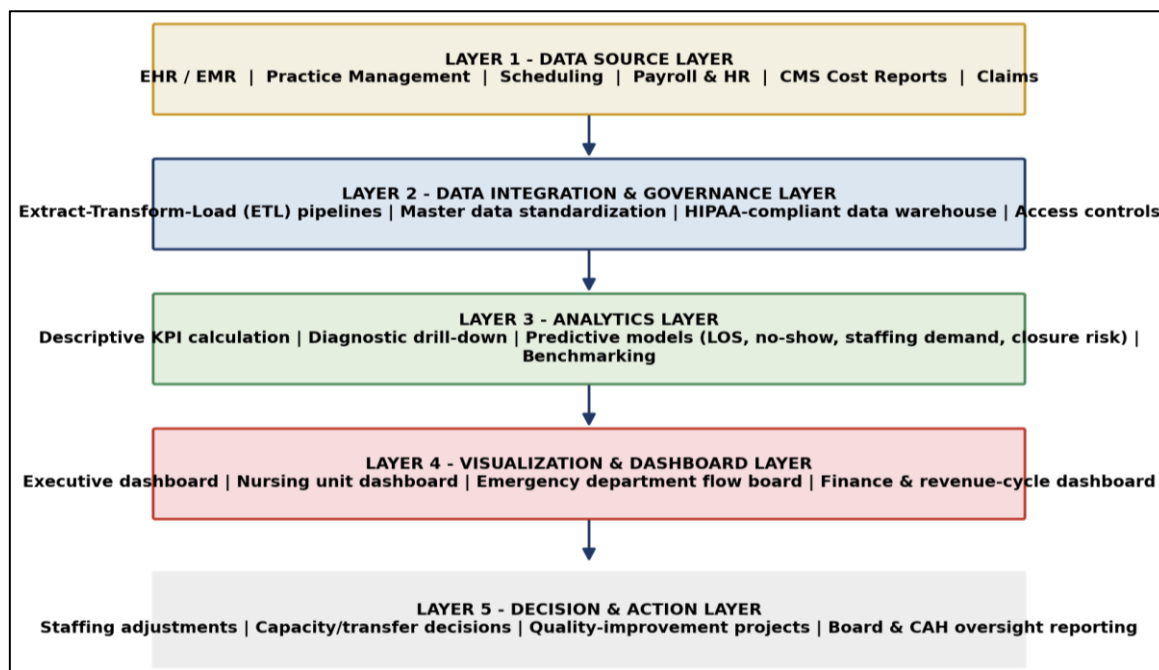


Fig 3 Five-Layer Conceptual Framework for Rural Hospital Business Intelligence Systems (Original Framework Developed for This Review).

The five layers are shown in a vertical stack in Figure 3, with each layer depending upon the reliability of the layer below it, to illustrate how health care BI implementations are generally staged in the published dashboard literature, not an arbitrary ordering convention (Dashboards in Health Care Settings: Protocol for a Scoping Review, 2022). The reason that data source and governance are placed at the base of the stack instead of being thought of first as a visualization layer is a conscious attempt to correct an implementation mistake that is often made when working in rural areas: purchasing a dashboard product before the data at its core is reliable enough for visualization.

Each layer in Figure 3 corresponds to one of the subsections detailed in Sections 4.1 through 4.4, and the framework is intended to be read top-to-bottom as a maturity progression rather than as five components a hospital must

build simultaneously; a facility that has only achieved Layer 1 and Layer 2 maturity can still derive value from the framework by focusing improvement effort on the next layer up rather than treating the full stack as an all-or-nothing implementation target (Binariks, 2026).

The framework in Figure 3 was intentionally synthesized to the rural context instead of being directly adapted from an enterprise health-system model, with functions combined into one layer more consistent with a one or two person IT department at a rural hospital, as described in Section 8.1, to make the framework usable by an informatics-poor hospital lacking dedicated staff for informatics/IT (The Digital Divide in Adoption and Advanced Use of Electronic Health Records Among US Hospitals, 2026).

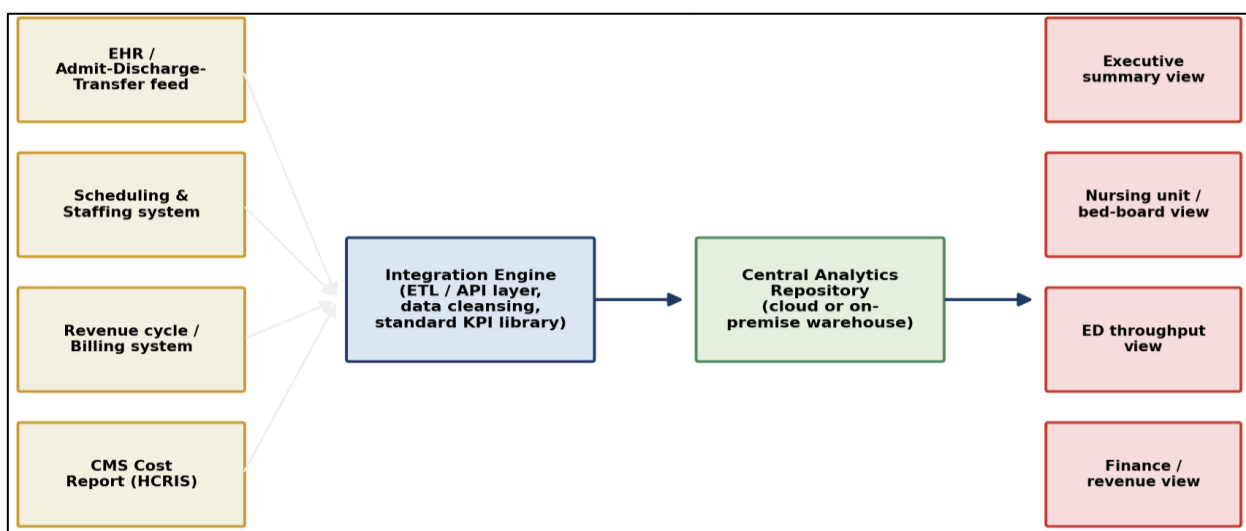


Fig 4 Rural Hospital Business Intelligence Data-Flow Architecture (Original Framework Developed for This Review).

Figure 4 shows the same five-layer architecture from a data-flow instead of a structural point of view, starting with the source system where the data is captured, moving to an integration point, an analytic transformation point, a visualization point, and finally a decision point. The second way to present the framework, as seen in Figure 3, is on purpose; it's what the leadership of a rural hospital should see as they're trying to figure out how to build it, and in Figure 4, it's what the same group of rural hospital leaders should see when they're trying to understand how a single piece of operational data, such as a bed-occupancy count, or an ED arrival timestamp, flows through the framework to become an actionable indicator on a dashboard.

The data-flow view in Figure 4 also highlights a failure point not shown in the structural view in Figure 3: data can be accurate at the source layer and end up in the visualization layer distorted, which aligns with concerns raised in other parts of the healthcare BI literature regarding the impact of unresolved data quality problems reaching end-users unfiltered (Healthcare Business Intelligence: Tools to Improve Patient Outcomes, 2024).

Figure 4 is not meant to be read as an engineering blueprint, but instead, it's meant to be used as a diagnostic tool: If the clinical or finance staff is concerned about a dashboard metric, they will trace the data flow, source capture, integration, analytics or visualization process to determine the most likely source of the discrepancy, as opposed to starting from scratch to audit the entire pipeline (SPD Technology, 2026).

➤ The AI-Enabled Decision Cycle Motivating the Framework

The five-layer architecture described above is not a pipeline that is statically configured, but rather a continuous, AI-driven decision loop whereby operational data feeds into the clinical and administrative outcomes it is intended to influence. Healthcare organizations that have advanced beyond descriptive reporting to embedded artificial intelligence (AI) have identified that the value of the technology can be summarized in two outcome areas: operational efficiency and patient outcomes, both of which rely on the same three layers of integration, analytics, and governance that this review proposes for rural settings (Artificial Intelligence in Nursing: An Integrative Review of Clinical and Operational Impacts, 2025).

The cycle is illustrated conceptually in Figure 5: decision-making and analytics personalization are placed on one side, while the other side of the cycle consists of high costs of implementation, the risk of data security, and staff resistance, with a set of implementation strategies, investments, staff training, and data governance somewhere in the middle (Malone et al., 2025; Barriers to Electronic Health Record Adoption: A Systematic Literature Review, 2016). In the case of a rural hospital with few resources and a small IT footprint, the logic is that challenges from half of the cycle can't simply be ignored by investing in more sophisticated analytics; they have to be addressed explicitly through the same investment, training, and governance processes discussed in Sections 8–10.

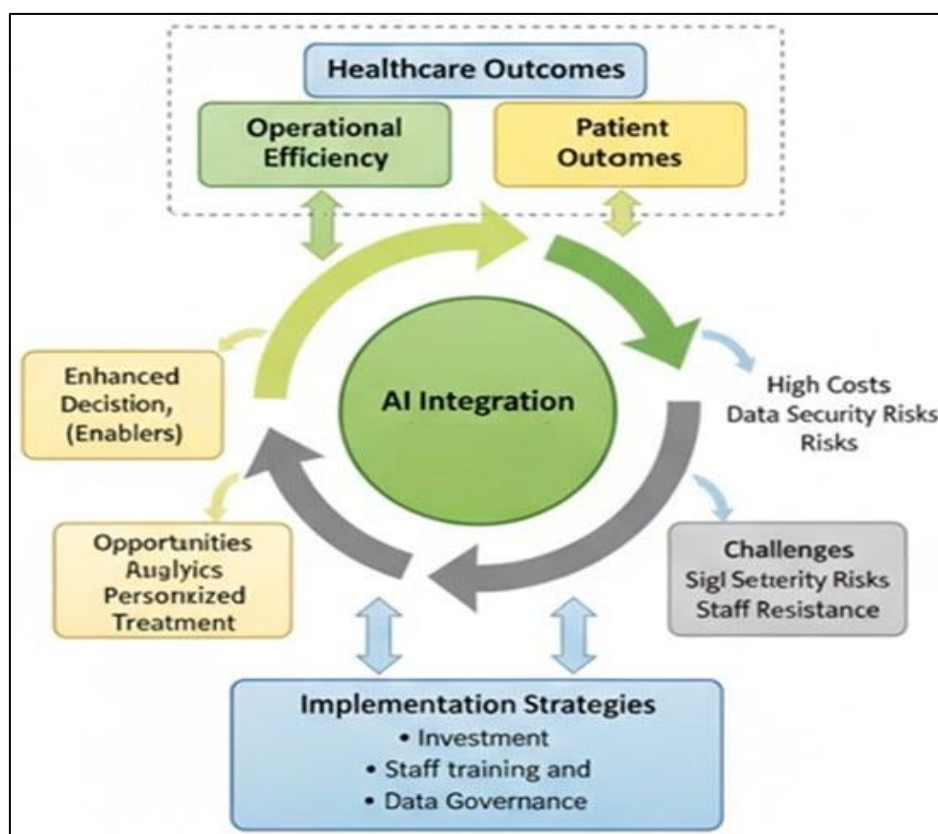


Fig 5 Conceptual Cycle Linking AI-Enabled Analytics to Operational Efficiency and Patient Outcomes, Mediated by Implementation Strategy (Illustrative Framework; Original Source not Independently Verified).

This cycle framing helps to explain why governance and workforce readiness, discussed in Sections 4.2 and 8.3, are not an after-thought in change management, but are part of the BI framework. The rural hospital that installs analytics, but doesn't invest in training staff and data governance, is really just creating the top half of the cycle depicted in Figure 5, which is missing the intermediary ability to put enhanced decision-making into practice with the hospital.

The cycle illustrated in Figure 5 aligns with other studies on the use of artificial-intelligence-enabled analytics in clinical care that found that measurable benefits focus specifically on the two areas of operational efficiency and patient outcomes (shown left side of the cycle), while the other areas of implementation costs, data-security risk, and staff resistance (shown right side of the cycle) were cited most often as reasons for delaying or outright abandoning

analytics initiatives before measurable benefits are achieved (Artificial Intelligence in Nursing: An Integrative Review of Clinical and Operational Impacts, 2025).

The inclusion of implementation strategy, investment, staff training, and data governance at the center of the cycle, not as an up-front expense, and not as an expense that a rural hospital is forced to incur before realizing the benefits, further emphasizes a central theme of this review: these mediating factors are not a one-off expense that a rural hospital needs to make before the benefits side of the cycle, but an operational requirement that must be met on an ongoing basis because a hospital that dabbles in training or governance, for instance, after an initial rollout runs the risk of falling back toward the resistance and risk factors on the right side (Barriers to Electronic Health Record Adoption: A Systematic Literature Review, 2016).

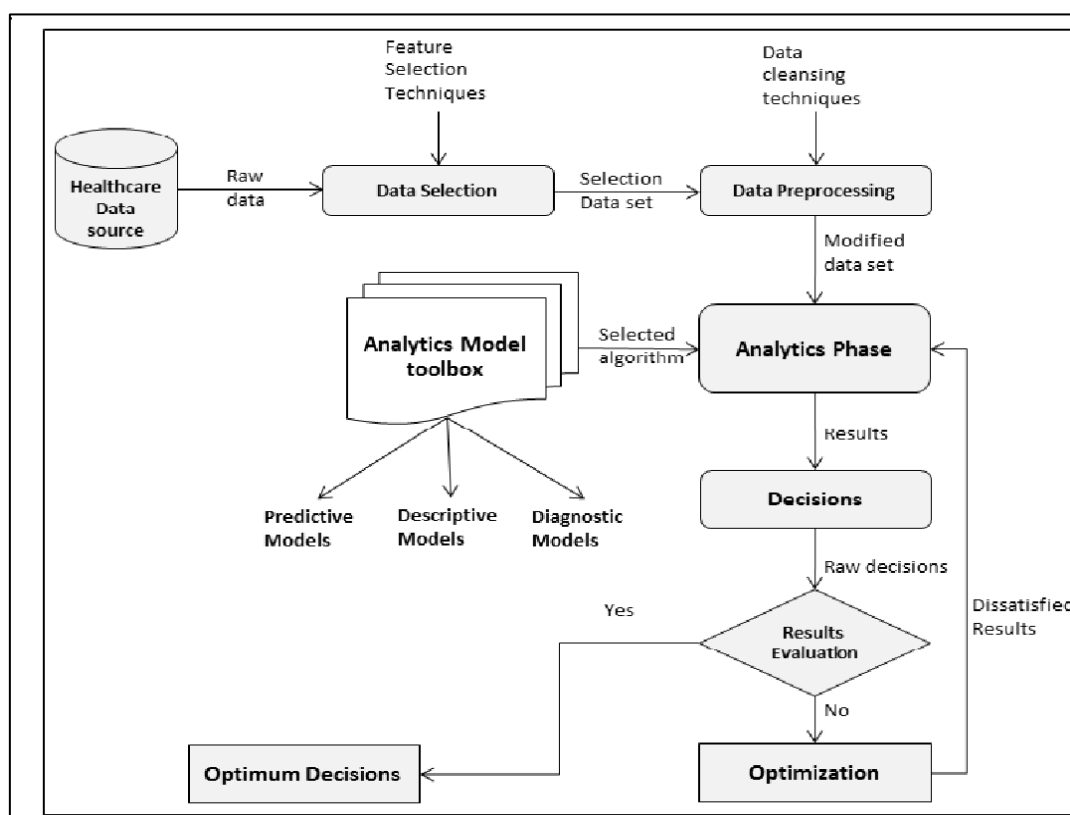


Fig 6 Data-Flow Architecture of the Analytics Layer, from Raw Healthcare Data Through Feature Selection and Model Application to Evaluated, Optimized Decisions (Adapted from Published Healthcare Analytics-Tier Literature; Original Source not Independently Verified).

The results-evaluation process outlined at the bottom of Figure 6 — where an unsatisfactory outcome leads to a return to an optimization step is similar to the recommended results-evaluation discipline for rural KPI dashboards as described in Section 6 — calculated measure that fails plausibility check: A calculated measure that fails plausibility check, such as an occupancy rate over 100%, due to a bed-count data error, should be investigated for data quality rather than published to end users as final since incorrect numbers can undermine staff confidence in the data, rather than simply being ignored (Healthcare Business Intelligence: Tools to Improve Patient Outcomes, 2024). The three model families highlighted in the

figure's analytics toolbox—predictive, descriptive, and diagnostic—are directly related to the steps of the analytics-layer maturity progression described in Section 4.3, providing rural administrators with a set of words to use when talking about where they're at with their analytics program and what additional capability they should invest in if they want to move to the next stage.

Unlike a typical reporting pipeline, this architecture adds an evaluation step before the results are published to end users, a design pattern that is found throughout the general healthcare analytics-layer literature, but not necessarily in the

context of this review (Data-Driven Healthcare: The Role of Business Intelligence Tools in Optimizing Clinical and Operational Performance, 2025).

Full utilization of the evaluation loop described in Figure 6 may not be practical in the early stages of implementation for a rural hospital with just one part-time

analyst; a slightly different approach is to have a checklist of common failure points, and have utilization rates above 100 percent, which may be calculated from an unusually small denominator, and applied manually before a new metric is added to a dashboard, but still carry out the intent of the evaluation step outlined in Figure 6 (UseDataBrain, 2026).

Table 2 Representative Data Sources Feeding Each Layer of the Proposed Rural Hospital BI Framework.

Framework Layer	Representative Data Sources	Typical Rural Availability
Layer 1: Data source	EHR / ADT feed, scheduling, payroll/HR, billing, CMS HCRIS cost report	Widely available; often disconnected
Layer 2: Integration & governance	ETL pipelines, master data standards, HIPAA-compliant warehouse	Frequently absent or manual
Layer 3: Analytics	KPI calculation engine, benchmarking feeds (e.g., CAHMPAS)	Rare without external support
Layer 4: Visualization	Executive, nursing-unit, ED-flow, and finance dashboards	Rare below CAH scale
Layer 5: Decision & action	Governance committee, escalation protocols, board reporting	Variable; often informal

As noted throughout this review, the availability of data for rural hospitals is quite limited when the framework extends from the source of the data to decision-making and action. (See Table 2.) Layer 1 data, drawn from EHR, scheduling, payroll, and CMS cost-report feeds, is widely available even in small facilities, yet layer 3 and layer 4 capability, KPI calculation engines and purpose-built dashboards, remains rare below the critical access hospital scale (Dashboards in Health Care Settings: Protocol for a Scoping Review, 2022). That is the reason for the “phased roadmap” in Section 10—where data-foundation investment happens before analytics and visualization investment—instead of all five layers being one massive purchase.

The layer of governance identified in Table 2, standards, HIPAA-compliant warehousing, and master data management, is often the most overlooked layer to hospital leadership, but also the most frequently cited in the BI literature as a prerequisite to the successful implementation of dashboards (Binarijs, 2026). Without the correct integration and governance layer in place, as outlined in Table 2, a rural hospital that buys a visualization tool may end up creating a dashboard atop of inconsistent or duplicated source data, or in a situation where source data is of poor quality, as may have occurred in many larger health system's initial BI deployments (Healthcare Business Intelligence: Tools to Improve Patient Outcomes, 2024).

Table 3 Rural Hospital Classification and National Facility Counts, 2023.

Indicator	Value	Source
Total U.S. community hospitals	5,112	American Hospital Association, 2025
Rural community hospitals	1,796 (35.1% of total)	American Hospital Association, 2025
Rural hospitals with 50 staffed beds or fewer	66% of rural hospitals	American Hospital Association, 2025
Rural hospitals with 100+ staffed beds	15% of rural hospitals	American Hospital Association, 2025
Critical Access Hospitals as share of rural hospitals	Approximately two-thirds	Yan et al., 2025
U.S. population living in non-urban areas (2024)	~46 million (14% of U.S. population)	ASPE, 2026
Rural hospitals closed or converted, 2010-2023	8% of rural hospitals (vs. 3.5% urban)	ASPE, 2026; USDA ERS, 2025

The national facility count numbers in Table 3 describe the overall size of the population this review seeks to address: Over a third of the nation's community hospitals are located in rural areas, while approximately two-thirds of the nation's rural hospitals are designated as Critical Access Hospitals, a designation directly linked to a cost-based federal reimbursement structure, which in turn have influenced the financial constraints discussed throughout Section 2 (American Hospital Association, 2025; Yan et al., 2025). That sixty-six percent of rural hospitals have fewer than fifty beds, as Figure 3 shows, is most responsible for the central design premise of this review—that a BI framework conceived and built for use in a five-hundred-bed academic medical center is unsuitable for rural use unless it is

developed specifically to meet the needs of these smaller facilities.

This closure and conversion rate, proportionately higher for rural hospitals than for urban hospitals (8 percent versus 3.5 percent, respectively) since 2010, is consistent with the evidence of access crisis presented in Section 1.1, which comes from a different data source and time window, increasing confidence that the rural-urban viability gap is not an artifact of any single dataset, but is a structural trend (ASPE, 2026; USDA ERS, 2025). Combined, the classification statistics in Table 3 define both the number of people that this framework, as proposed in Section 4, could affect and the limits on the resources that it would consume.

V. OPERATIONAL EFFICIENCY METRICS FOR RURAL HOSPITAL DASHBOARDS

Rural hospital administrators have access to many more candidate metrics than they can easily monitor and manage, so prioritization is key. In this section, four of the more frequently recurring families of operational metrics are reviewed, which include bed utilization, length of stay (LOS), efficiency of discharge, emergency department throughput (EDT), and staffing ratios (SR), and which are directly applicable to the tactical and operational levels of the KPI hierarchy illustrated in Figure 7.

➤ *Bed Utilization and Occupancy Indicators*

The proportion of staffed beds that were occupied on a particular day of the week or month is the most widely reported measure of hospital capacity, defined as the number of occupied bed-days divided by the number of available staffed bed-days on the same day of the week/month, and expressed as a percentage. This is particularly true for a small rural facility with, say, twenty-five staffed beds, as the number of patients coming in and out of the hospital each day is a fairly strong predictor of closure risk for such facilities (Chartis Center for Rural Health, 2026) and is included in the Chartis rural hospital vulnerability model. Occupancy tracking can become more complicated if your rural hospital has swing beds, which can be used to switch between a bed being used for acute or skilled-nursing care as needed each day.

Rural hospitals generally have lower average occupancy than urban hospitals, so occupancy alone is a less complete measure of efficiency, as a dashboard that only reports occupancy could lead administrators to believe that the low figures are a sign of an oversized hospital, instead of a sign of a hospital serving a sparse, dispersed population where maintaining unused capacity is a clinical necessity, not an inefficiency. Smaller size and lower occupancy rates are explicitly cited by USDA Economic Research Service analysis as factors in increased likelihood of closure, but the analysis does not suggest that smaller rural hospitals should be built to ensure higher rates of occupancy in order to ensure better services for patients, as such, essentially would be killing those services that make the hospital necessary. (USDA ERS, 2025).

➤ *Average Length of Stay and Discharge Efficiency*

Average length of stay (ALOS), usually defined as the number of inpatient bed-days divided by the number of discharges over a given period, is both a measure of cost-control and a measure of quality of care as too long an inpatient stay wastes limited bed capacity and increases the risk of hospital-acquired complications. The average length of stay mathematically as:

$$LOS_{avg} = (\sum_{i=1}^n d_i) / n$$

d_i is the discharge to admission interval (in days) of the i -th of n discharged patients in the reporting period. One downside of frequent lack of post-acute hospital placement is

that, particularly in rural areas, a patient may simply not be medically ready to be discharged because there is no skilled nursing facility or rehabilitation bed available close enough to the hospital for transfer.

Three metrics that are natural companions to ALOS on a rural dashboard are: the percentage of patients discharged prior to a defined daily target time, the percentage of delays due to non-clinical factors (e.g., transportation or placement availability), and thirty-day readmission rate (discussed further in Section 6.1 as an outcomes-related measure). These can be tracked together and administrators can then identify clinically necessary length of stay versus avoidable, system-driven delay, which is significant when considering bed capacity within the context of demand variation, particularly in rural settings where beds are constrained.

➤ *Emergency Department Throughput Indicators*

The throughput of the ED is one of the most operationally easily measured metrics in any hospital, rural or urban, and ED delays are directly observable by the patient and family whereas back-office delays are not. Crowding, Boarding, and Patient Throughput in the Emergency Department 2025 is a national summit specifically convened by the Emergency Department Benchmarking Alliance to define the core indicators for the measurement of ED throughput: door-to-provider time, ED length of stay and boarding time as formally defined. The time between a child being accepted to an ED for an inpatient admission and admission to an inpatient bed ('boarding time') was relatively poor across the country and is especially concerning for rural EDs, who have less inpatient bed buffer, having increased from a median of one hundred nineteen minutes in 2019 to approximately one hundred ninety-two minutes in 2023 (Crowding, Boarding, and Patient Throughput in the Emergency Department, 2025).

A four-year retrospective study at one hospital revealed that the percentage of patients who left without completing service was strongly associated with ED length of stay, boarding time, and door-to-doctor time, all of which have worsened over the past two years from 6.47 percent in 2019 to 16.12 percent in 2022 (Annals of Emergency Medicine, 2023). An operational to natural bridge indicator between the operational and financial levels of a rural hospital dashboard, left without completing service events are a safety problem and also represent a direct revenue loss as a patient who leaves before they are seen generates little or no billable service (Annals of Emergency Medicine, 2023).

The impact of ED boarding on flow is not limited to the ED. In one study, there was a positive statistically significant correlation between non-trauma patient boarding time and trauma patient ED Length of Stay in the same facility (Pearson correlation coefficient of 0.73) and this was found to be statistically significant (one study) (Adversely Affecting the ED throughput for Trauma patients, a positive statistically significant correlation between non-trauma patient boarding time and trauma patient ED length of stay in the same facility, 2020). This "cross-contamination" effect will likely be even more significant for rural EDs, where there is no dedicated

trauma and general bays but rather a single, general bays, and so a single ED flow dashboard will be more beneficial than reporting in silos by patient type.

Hospitals, for example, are now mandated to report on new federal requirements for an Emergency Care Access and Timeliness measure that includes four outcomes, including overall ED length of stay for discharged patients, where combined arrival-to-departure wait time is more than eight hours deemed a poor performance (Healio, 2025). This approach will be applied on a national basis, so rural hospitals who are currently building BI dashboards for EDs now have an immediate incentive to standardise the tracking of ED throughput before the reporting requirement rather than having to do this potentially under regulatory pressure at a later stage.

➤ *Staffing Ratio and Labor Cost Indicators*

Staffing measures lie at the nexus of financial and clinical measures more closely than most rural hospital measures, as labor costs are often the largest controllable expense line on a rural hospital's cost report and the measure of safety margin available for patient care. Some of the key staffing measures for a rural dashboard are nurse to patient ratio by unit and shift, the percentage of the nursing hours staffed by contingent or travel staff, and overtime hours as a

percentage of total hours worked. According to national surveys, hospital nursing departments today have an average of twelve percent contingent nurses—a reliance on contract labor that adds financial pressure to already tight rural operating margins (ChartSpan, 2025).

The monetary risk incurred due to staff shift is significant and measurable. Nurse turnover rate is a significant leading indicator of future labor cost pressures on a rural hospital's income statement as it can cost between \$45,100 and \$67,500 to replace a single registered nurse, according to a NRHA 2024 national retention and staffing report, with the average time to hire a new nurse being fifty-nine to one hundred nine days. A dashboard revealing turnover and contingent-labor trends early provides rural leaders with a more relevant time horizon to respond than waiting for the impact to be seen in quarterly financial statements, especially since about half of rural hospitals were already working at a loss in 2024, in part due to challenges in staffing (ChartSpan, 2025).

- *Equation 1. Average Length of Stay.*

$$\overline{LOS} = \frac{\sum_{i=1}^n d_i}{n}$$

- *Equation 2. Bed Occupancy Rate.*

$$OccupancyRate = \frac{\sum Occupied\ Bed - Days}{\sum Available\ Staffed\ Bed - Days} \times 100\%$$

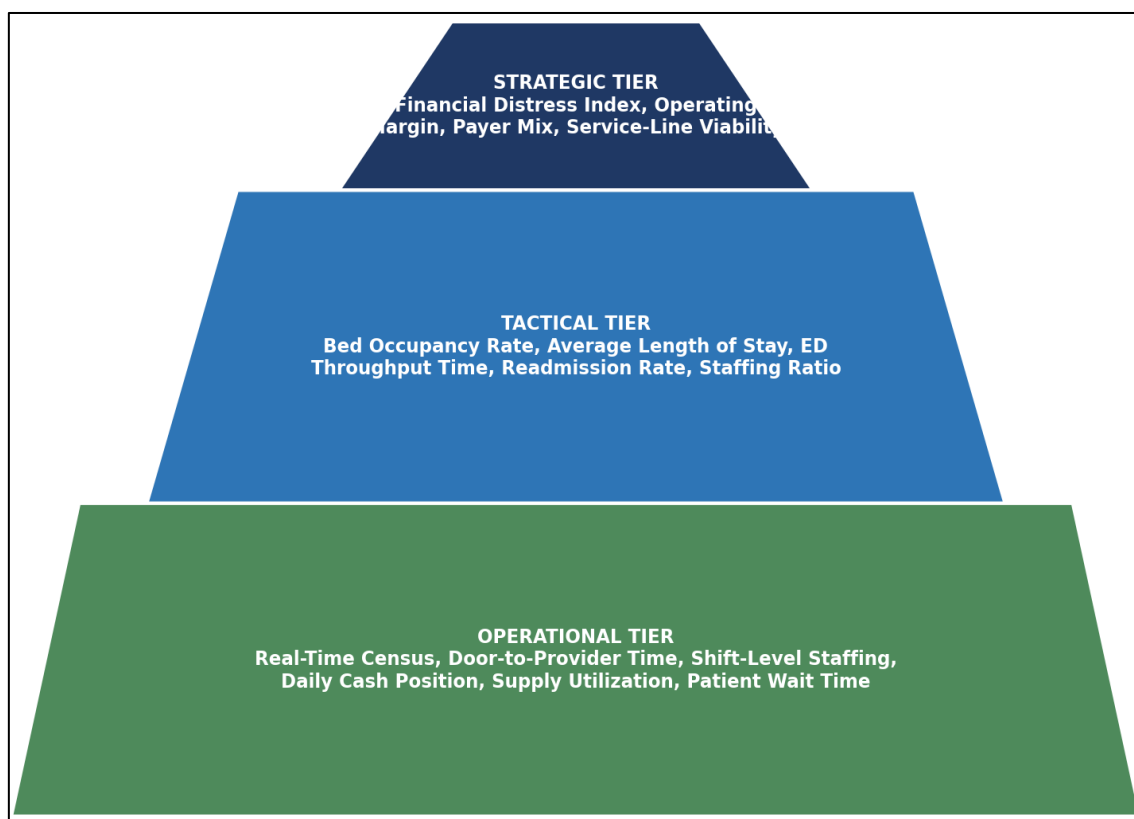


Fig 7 Three-Tier Key Performance Indicator (KPI) Hierarchy for Rural Hospital Dashboards (Original Framework Developed for This Review).

The individual KPIs listed in Table 4 are grouped into three tiers – strategic, tactical and operational – by the review cadence and by the group of audience that each indicator is best suited to, and not by the clinical or financial subject matter. Once a strategic tier indicator like overall operating margin or an operational tier indicator like nurse to patient ratio is “shown” on the dashboard, it is refreshed as frequently as every month or quarter by the hospital leadership, or as frequently as every hour or minute by a charge nurse, respectively.

This cascaded presentation is intended to avoid the common scenario in which a rural hospital's initial dashboard

attempts to present all of the available data in the same manner, causing it to become so voluminous that the small team charged with responding to the data become overwhelmed. Each of the KPIs in Table 4 is assigned to a tier in the hierarchy in Figure 7, making it easier for a resource-limited rural team to make decisions about which indicators to include on a daily operational screen and which to include in a monthly governance report, as described in the adoption literature, where ease of use was identified as a more powerful driver of sustained dashboard use than analytic sophistication (Healthcare Business Intelligence: Tools to Improve Patient Outcomes, 2024).

Table 4 Core Operational Efficiency KPIs Proposed for Rural Hospital Dashboards, with Calculation Formulas.

KPI	Formula / Definition	Tier	Rationale
Bed occupancy rate	$\text{Occupied bed-days} \div \text{Available staffed bed-days} \times 100$	Tactical	Core capacity signal; feeds Chartis vulnerability model
Average length of stay (ALOS)	$\text{Total inpatient bed-days} \div \text{Total discharges}$	Tactical	Cost and quality signal; sensitive to post-acute placement gaps
ED door-to-provider time	$\text{Time of provider contact} - \text{Time of ED arrival}$	Operational	First-contact speed; EDBA standardized definition
ED boarding time	$\text{Time of bed assignment} - \text{Time of admit decision}$	Operational	National median rose from 119 to 192 minutes, 2019-2023
Left without completing service (LWCS) rate	$\text{Patients leaving before evaluation} \div \text{Total ED visits} \times 100$	Operational	Correlated with LOS/boarding; safety and revenue signal
Nurse-to-patient ratio	$\text{Staffed RN FTEs} \div \text{Average daily census, by unit/shift}$	Operational	Safety margin; linked to turnover-driven labor cost
Contingent labor share	$\text{Contract/travel nursing hours} \div \text{Total nursing hours} \times 100$	Tactical	National average of 12%; leading indicator of labor-cost pressure
Discharge-before-target-time rate	$\text{Discharges before 2:00 p.m.} \div \text{Total discharges} \times 100$	Operational	Distinguishes avoidable from clinically necessary delay

Many of the operational KPIs outlined in Table 4 were chosen, in part because of their known responsiveness to the ED throughput and staffing pressures discussed above. Boarding time and its partner indicator, left without completing service rate, are among the operational indicators that have seen significant increases over time and thus are candidates for near real time dashboard reporting, not retrospective reporting, from 2019 through 2023 (Table 4) (Healio, 2025; Annals of Emergency Medicine, 2023).

Several of the indicators from the tactical tier in Table 4 also directly relate to the financial distress indicators discussed in Section 2.2, and if a rural hospital's contingent labor share is above the national average of approximately twelve percent, they are also signalling a staffing-adequacy problem, which is why the indicators in Table 4 should not be interpreted in isolation from the indicators in Table 5 and Section 6; they should be interpreted together (Karim et al., 2026).

VI. PATIENT OUTCOME METRICS AND THEIR FINANCIAL LINKAGES

When it comes to patient outcomes versus operational efficiency, these are not two opposing goals in a well-designed rural hospital BI system—they're the same thing

from different perspectives. This section reviews outcome metrics that are most closely linked to the operational indicators enumerated in Section 5, paying special attention to the financial consequences that result when outcome metrics decline.

➤ Readmission Rates and Quality Indicators

One of the most commonly reported hospital quality metrics on the national level is the 30-day all-cause readmission rate, and it is often the one rate that is directly tied to a hospital's exposure in the CMS Hospital Readmissions Reduction Program. For example, BI-enabled population health programs can have a dramatic impact on reducing hospital readmissions, as shown in case evidence from one large pediatric health system that, through the use of dashboards and predictive analytics, they are able to identify high-risk patients for targeted intervention and thereby successfully cut hospital readmissions by thirty percent and their chronic disease management outcomes by twenty percent (as cited in The Role of Business Intelligence Tools in Improving Healthcare Patient Outcomes and Operations, 2024).

In rural hospitals in particular, the metrics that one would hope to see on a readmission dashboard—along with the raw readmission rate—should include contextual drivers

such as percentage of patients discharged who follow up within seven days for an outpatient specialty visit, as well as patient transportation availability in the community, since a miss in outpatient specialty follow-up could be a reasonable goal for a rural hospital care-coordinating program to address, and a failure to address it could result in an avoidable readmission.

➤ *Maternal and Obstetric Outcome Indicators*

With the nearly 25% of the country's rural hospitals discontinuing obstetric services between 2011 and 2023 (Chartis Center for Rural Health, 2026), viability of obstetric services has emerged as one of the most impactful outcome domains in the discussions about rural health policy. Public health researchers warn that it's a combination of several factors, and that the number of births in the country has actually fallen significantly with approximately six hundred eighty-seven thousand fewer births in 2024 than in 2007, but that financially motivated service closures have also not always been coordinated with the affected communities (Boston University School of Public Health, 2025). A rural hospital that is keeping obstetric services is well justified in having the number of deliveries, the number of transfers to obstetric hospitals, and the number of postpartum hospital readmissions as core outcome measures both to keep track of the ongoing clinical need for the service line and to proactively recognize early warning signs before the service line becomes financially unsustainable.

Since obstetric closures impact emergency department utilization, the experience of presenting to the ED during a labor complication should have a place in a comprehensive rural BI dashboard, not be relegated to just one department's report.

➤ *Patient Safety and Adverse Event Indicators*

Patient safety indicators, such as hospital-acquired infection rate, fall rate, and medication-error rate, continue to be essential elements of any hospital quality dashboard, but there is a catch with these indicators in rural hospitals: with less overall hospital volume, a rural hospital may only have a handful of adverse events over a month, causing the month-to-month comparisons to be statistically noisy, and potentially leading to the wrong interpretation if presented without the appropriate control limits or rolling averages. A rural BI dashboard should, therefore, incorporate rolling 12-months rates and statistical process control charts, instead of single-month snapshots, for the safety indicators as this is more relevant to rural environments with a smaller sample size of monthly records compared to the larger monthly sample size in urban hospitals.

The rate of left without completing service (LWCS) is another indicator of ED throughput, introduced in Section 5.3, and is also a patient safety indicator because patients who are discharged without completing an evaluation may have emergent conditions that have not been addressed. The demonstrated relationship between this rate and ED length of stay and boarding time (Annals of Emergency Medicine, 2023) highlights the fact that a single, well-designed ED dashboard can address an operational efficiency signal, a financial-leakage signal, and a patient-safety signal as well, making the metric families in Sections 5 and 6 better understood as an interconnected system rather than distinct reporting silos.

- *Equation 3. Thirty-Day All-Cause Readmission Rate.*

$$\text{ReadmissionRate} = \frac{N_{\text{readmit}, \leq 30 \text{ days}}}{N_{\text{discharges}}} \times 100\%$$

Table 5 Core Patient Outcome KPIs Proposed for Rural Hospital Dashboards, with Calculation Formulas.

KPI	Formula / Definition	Tier	Rationale
30-day all-cause readmission rate	Readmissions within 30 days ÷ Total discharges × 100	Strategic	Drives CMS Hospital Readmissions Reduction Program exposure
7-day post-discharge follow-up completion	Completed follow-up visits ÷ Discharges × 100	Tactical	Distinguishes access-driven from severity-driven readmission
Obstetric transfer rate	Maternal/neonatal transfers out ÷ Total deliveries × 100	Tactical	Early signal for service-line sustainability
Postpartum readmission rate	Postpartum readmissions ÷ Total deliveries × 100	Tactical	Quality indicator for retained obstetric service lines
Hospital-acquired infection rate	New infections ÷ Patient-days × 1,000 (rolling 12-month)	Operational	Requires rolling average given low rural monthly volume
Fall rate	Inpatient falls ÷ Patient-days × 1,000 (rolling 12-month)	Operational	Statistical process control preferred over monthly snapshot
Left without completing service (LWCS) rate	See Table 4	Operational	Dual operational/safety indicator

Therefore, the outcome indicators presented in Table 5 were deliberately matched with the operational indicators presented in Table 4, instead of being used as a separate reporting stream; this was the key principle of this review, that operational efficiency and patient outcomes are two ways of looking at the same process. The thirty-day readmission

indicator is the only outcome measure that is most directly tied to financial exposure, as it affects a hospital's ranking in the CMS Hospital Readmissions Reduction Program, and the obstetric transfer and postpartum readmission indicators in Table 5 are directly related to the pressures on service lines

identified in Section 1.1 (Chartis Center for Rural Health, 2026).

These rolling 12-month calculation windows are a conscious choice and not a standard convention for reporting rates: because the number of patients receiving care at rural hospitals may be low, the single-month calculation window may lead to statistically unreliable results; and a dashboard that reports on a monthly safety rate would result in a false sense of security or alarm due to random monthly variation in performance (Malone et al., 2025). This same low-volume constraint, which will be detailed later in Section 6.3, is one of the most universally apparent to show that it is impossible to take a BI framework that is suited to an urban hospital and simply transfer it to rural hospitals.

VII. COMPARATIVE ANALYSIS OF BUSINESS INTELLIGENCE TOOL OPTIONS

Platform selection is often the first concrete step taken when a rural hospital decides to take a data-driven approach, and ideally, should come after, rather than before, the framework and metric-prioritization process described in Sections 4 through 6. This section provides a comparison of the major categories of BI tools in terms of their cost, capability, and suitability for resource-limited environments in rural hospitals.

➤ Enterprise-Grade Commercial Platforms

Tableau, Qlik Sense, and Domo are enterprise commercial BI platforms that provide the most visualization and enterprise governance but the licensing expenses do not scale well for small rural systems. Market comparisons are made in the thousands of dollars per month, with the total cost of ownership for Tableau Creator ranging from about \$7,500 per month, Qlik Sense \$3,000 to \$5,000 per month and Domo \$8,300 per month, and in the first year, alone, with implementation, training, and ongoing administration costs, typically one and a half to three times as much as the license cost (Power BI Consulting, 2026). To put these numbers in perspective, these are the numbers illustrated in Figure 8 and are significantly higher than the full enterprise-tier licensing for most rural critical access hospitals without outside grants.

Microsoft Power BI falls somewhere in the middle of the commercial platforms. Many rural hospitals are already running Microsoft 365 based on the Microsoft 365 technology stack for email, scheduling, and office productivity, making Power BI's ability to integrate with Excel and the rest of the Microsoft suite even easier to implement than other dashboards that require a completely separate technology stack (OvalEdge, 2026). Power BI is a much more affordable option than Tableau or Domo, starting at around \$1,000 per month for a 100-user Power BI Pro deployment, and with a true free desktop tier for one analyst, it's a much more appealing option for organizations that want to scale their analytics program over time (Power BI Consulting, 2026; Toolradar, 2026).

➤ Low-Cost and Open-Source Alternatives

Open-source BI platforms are the most cost-effective option for the smallest and most financially challenged rural hospitals. Today, Metabase is seen as the premier open-source BI tool: It provides a completely free self-hosted deployment and has a very simple, non-technical interface for asking questions to its data, which will be used by the hospital staff without any knowledge of SQL, but will still allow the more technical to write their own for when they need to. (Performance Reviews Software, 2026) Similar to Superset, Apache Superset is an open-source solution, licensed under Apache 2.0, which is more user-friendly for embedding dashboards into a hospital's internal portal than other dashboards that are more restrictively licensed (UseDataBrain, 2026).

The actual trade-off of open-source tools isn't license cost, which is essentially free, but the implementation and maintenance manpower required: the self-hosted open-source BI deployment still requires someone with enough technical acumen to install, configure, secure and maintain the underlying server infrastructure, and this is a resource that is scarce in rural hospital IT departments (Explo, 2025; Valiotti Data, 2026). But a small, rural hospital switching to an open-source platform should expect to spend either a small amount on a managed-hosting contract or a specific amount of the time of a current IT employee, not the zero-licensing cost to be its total cost.

➤ Cost-Benefit Comparison for Resource-Constrained Facilities

Table 6 compares the costs, capabilities, and rural-fits of five representative categories of BI platforms. As Table 6 illustrates, they vary several orders of magnitude between the lowest and highest tier of platforms at typical deployment size and that is precisely why platform selection is not independent of the phased implementation strategy outlined in Section 10: the critical access hospital that would try to fund the licensing of Tableau or Domo in their first year of BI adoption is much more likely to drop the project when the next budget cycle tightens, rather than the hospital that starts with the free or low cost tier and upgrades as the project proves value internally.

Price isn't, however, the sole factor to consider when selecting a platform. Power BI's seamless integration with the Excel app is a feature that would be understated by a straight-up cost comparison and gives a hospital that already uses Microsoft 365 meaningful implementation-speed benefits, while a hospital whose part-time data analyst is familiar with SQL can glean more value from the self-hosted flexibility of Metabase or Superset than from a bound commercial contract. The platform decision should be a step that comes after, not before, the data-source inventories carried out during the first layer of the framework (Section 4.1).

The pricing pressure that rural hospitals are experiencing in choosing a BI platform is occurring in the midst of the overall market growth. The global expenditure on healthcare business intelligence technology is expected to grow at a compound rate of 14.6% to reach about \$35.7

billion by 2034, and this will demonstrate the increase in the demand for analytics capability across the healthcare industry, both rural and urban (Precedence Research, 2025).

For a rural hospital evaluating vendors, this growth trajectory cuts in two directions. Over time, a fast-growing vendor market generally results in greater competition among BI platform vendors as they fight for market share outside the

large health-system market (Toolradar, 2026). Meanwhile, the lion's share of the market growth is in enterprise-oriented, AI-enhanced analytics solutions for the needs of large integrated delivery networks (IDNs), which are quite irrelevant to, and perhaps even a distraction from, the descriptive-analytics requirements of a fifty-bed critical access hospital (Power BI Consulting, 2026).

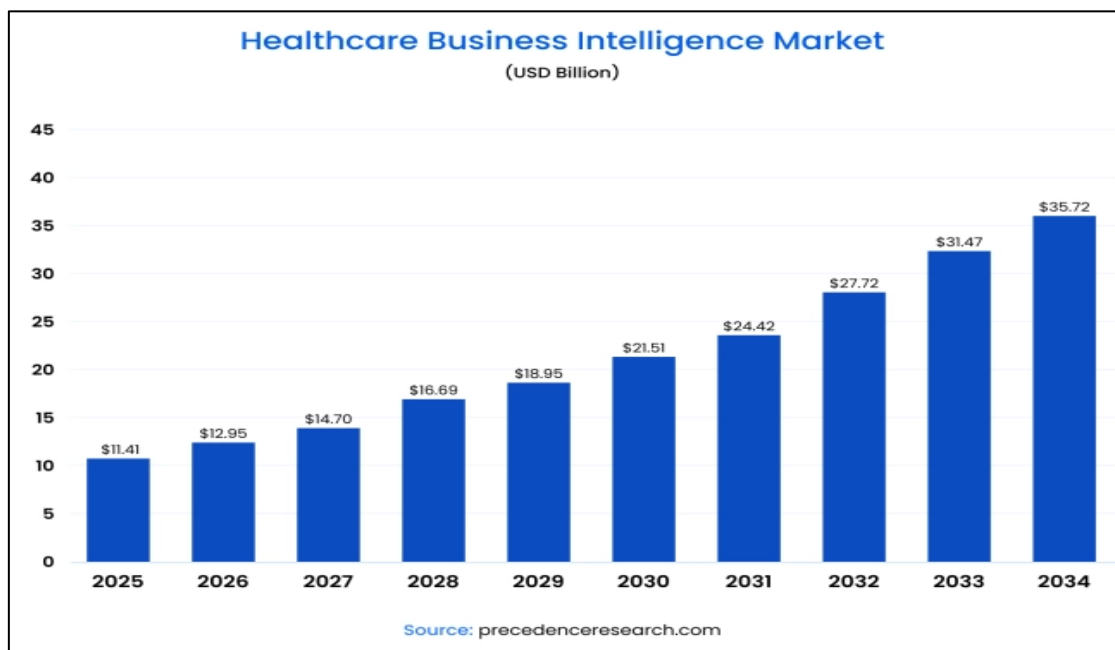


Fig 8 Projected Global Healthcare Business Intelligence Market Size, 2025-2034, USD Billions (Source: Precedence Research, 2025).

Rural administrators should understand that the growth rates of market segments in terms of the number of hospitals (as shown in the data in Figure 8) should be viewed as context, and not necessarily an indicator of which segment of the vendor landscape is best suited to meet the needs of a

smaller facility (with fewer than fifty staffed beds) with a restricted budget. The cost-tier comparison described in Table 6 is not the only metric to consider when choosing a platform, but it is a more direct and actionable input to the phased approach to platform selection outlined in Section 10.

Table 6 Comparison of Business Intelligence Platform Categories on Cost, Capability, and Rural-Facility Fit.

Platform Category	Approx. Monthly Cost (100 Users)	Key Strength	Key Limitation for Rural Facilities
Metabase (self-hosted, open-source)	License-free; hosting/labor cost only	No license fee; non-technical query interface	Requires in-house or contracted technical maintenance
Apache Superset (open-source)	License-free; hosting/labor cost only	Apache 2.0 license; embeds well in internal portals	Steeper setup curve than Metabase
Microsoft Power BI (Pro)	≈ \$1,000	Deep Excel/Microsoft 365 integration; free desktop tier	Cloud sharing tier still a recurring cost at scale
Qlik Sense	≈ \$3,000-\$5,000	Strong associative data-modeling engine	Cost and complexity high for single-facility use
Tableau (Creator)	≈ \$7,500	Best-in-class visualization depth	Pricing scales poorly; steep learning curve
Domo	≈ \$8,300	Integrated data pipeline plus visualization	Highest-cost tier; enterprise-oriented licensing

The range of costs outlined in the Summary of costs section (Table 6) is approximately two orders of magnitude from an effectively free deployment of Metabase on your own to an eight-thousand dollar per month subscription to Domo, and is directly tied to the phased implementation plan

proposed in Section 10 (Power BI Consulting, 2026; Performance Reviews Software, 2026). This should be determined by the platform's feature list, but not just that; the advantages of a rural hospital's current technology environment should also be taken into consideration, as

Power BI's support for the built-in Excel integration provides implementation-speed benefits that a comparison of costs outlined in Table 6 does not fully do justice to (OvalEdge, 2026).

The open-source solutions in Table 6, Metabase and Apache Superset, are driven by the need for technical expertise to install, secure, and maintain them, rather than the cost of licenses (UseDataBrain, 2026; Valiotti Data, 2026). In Section 8.1 we emphasized that the informatics-staffing shortage has become a reality, and that a rural hospital considering the options in Table 6 should consider all the labor costs of implementation and maintenance, rather than just the cost of the license line item.

VIII. BARRIERS TO BUSINESS INTELLIGENCE ADOPTION IN RURAL HOSPITALS

The challenges rural hospitals face in implementing BI tools are neither technical nor monetary, but they are interconnected, with each challenge driving the others. This section categorises the barrier landscape into four groups (summarised in the Table 7) and in Section 10 suggests a roadmap that will attempt to tackle each of these groups in turn.

➤ *Technical and Infrastructure Barriers*

In many rural areas, the adoption of cloud-based BI tools is hindered by the lack of reliable broadband internet connection; and research on barriers to rural telehealth adoption has universally found limited or unreliable broadband to be a root cause issue for any technology-based care or analytics effort (Nurse.org, 2025). In addition to connectivity, rural hospitals often have a myriad of complementary legacy systems, an older EHR system, a separate scheduling system, and a separate billing system that were never designed to communicate with each other and require significant custom “engineering” to do so in practice (Barriers to Electronic Health Record Adoption: A Systematic Literature Review, 2016).

Another often-overlooked obstacle is the lack of informatics expertise in rural hospital IT departments, which are frequently composed of one or two generalists who have to develop BI products on top of the various technology systems in the hospital, such as the phone system, the EHR, physical network security, etc. (The Digital Divide in Adoption and Advanced Use of Electronic Health Records Among US Hospitals, 2026).

➤ *Financial and Capital Constraints*

With approximately 40% of rural hospitals losing money on patient services alone, and nearly one third losing money overall in 2024 and 2025, the funds for a discretionary technology investment like a BI platform are competing with far more pressing considerations: payroll, medical supplies, building maintenance, and more (Becker's Hospital Review, 2026). This dynamic results in a structural paradox: hospitals that most need early-warning financial distress analytics often

lack the financial resources to support the analytics program that can give them that warning.

Federal support programs partially offset this constraint. The USDA ERS research indicated that rural hospitals with CFP funding were significantly more likely to survive than their peers, which means federal capital programs, for which a BI program is not a primary goal, could conceivably be scaled up, or even scaled back, to accommodate the investments in the data-infrastructure a BI program requires (USDA ERS, 2025).

➤ *Workforce and Analytics Literacy Barriers*

Having a well-funded and technically robust BI platform is not of any benefit if the hospital team isn't skilled in interpreting and applying the findings. Rural hospitals are already experiencing the nurse and physician shortages described in Section 2.2 and most often do not have the resources to hire a dedicated data analyst or informatics specialist to handle their BI needs, which are often added to the workload of an already overburdened chief financial officer, quality director, or IT generalist (National Center for Health Workforce Analysis, 2024).

When it comes to the tools they use for health analytics, that power comes with a learning curve, and a powerful platform is not necessarily going to be adopted by frontline employees if they lack the bandwidth to learn it—exactly why trust in data quality and ease of everyday use are always cited as the biggest motivators for frontline employees to use a dashboard in their day-to-day decision-making, as opposed to the platform's raw analytic capabilities (Healthcare Business Intelligence: Tools to Improve Patient Outcomes, 2024).

➤ *Cultural and Organizational Resistance Factors*

While some rural hospitals have expressed resistance to data-driven decision making, this resistance is not just against data-driven decision making, but is often influenced by prior experiences with data technologies, especially EHRs that were mandated in hospitals from the top down and that did not support clinical workflow but instead disrupted it (Barriers to Electronic Health Record Adoption: A Systematic Literature Review, 2016). When a new analytics initiative comes along and is presented in a similar top down approach, staff that has endured an awkward EHR transition are hesitant.

The implementation of a formal KPI governance process (Section 10.2) can also be a greater cultural change for smaller, more relationship based rural hospitals that typically have less formal reporting structures than larger, urban hospitals where these processes are commonplace. While mandate alone is not the most effective solution to overcome this resistance over time, the use of dashboard data for executive sponsorship and visible leadership in actual meetings has shown to be the most effective solution (Healthcare Business Intelligence: Tools to Improve Patient Outcomes, 2024).

➤ Organizing Governance, Implementation, and Solution Services

As with enterprise BI engagements, as described in the scoping of enterprise BI engagements, the cultural and workforce barriers listed above are best addressed through a defined taxonomy of services that are distinct from governance, implementation, and solution delivery, and which is followed by vendors and consulting firms. Figure 9 shows a sample taxonomy of these services and is split into three tracks—analytics and business intelligence, services, and solutions—all of which support the same overarching goal.

The first track is for services to support BI management, which include governance, organizational awareness and

strategy, the same executive-sponsorship and data-quality-trust services that were identified in Sections 4.2 and 8.4 as key factors in whether or not a dashboard is used by rural staff when it is present. The second track for services for BI implementation addresses the technical analysis, concept design, and development of a tool-portfolio that were discussed throughout the Sections 4 and 7 (National Center for Health Workforce Analysis, 2024); and the third track for solutions addresses supporting functions such as data warehousing, the human resources needed to staff an ongoing analytics function, a resourcing constraint discussed in Section 8.3 (National Center for Health Workforce Analysis, 2024).

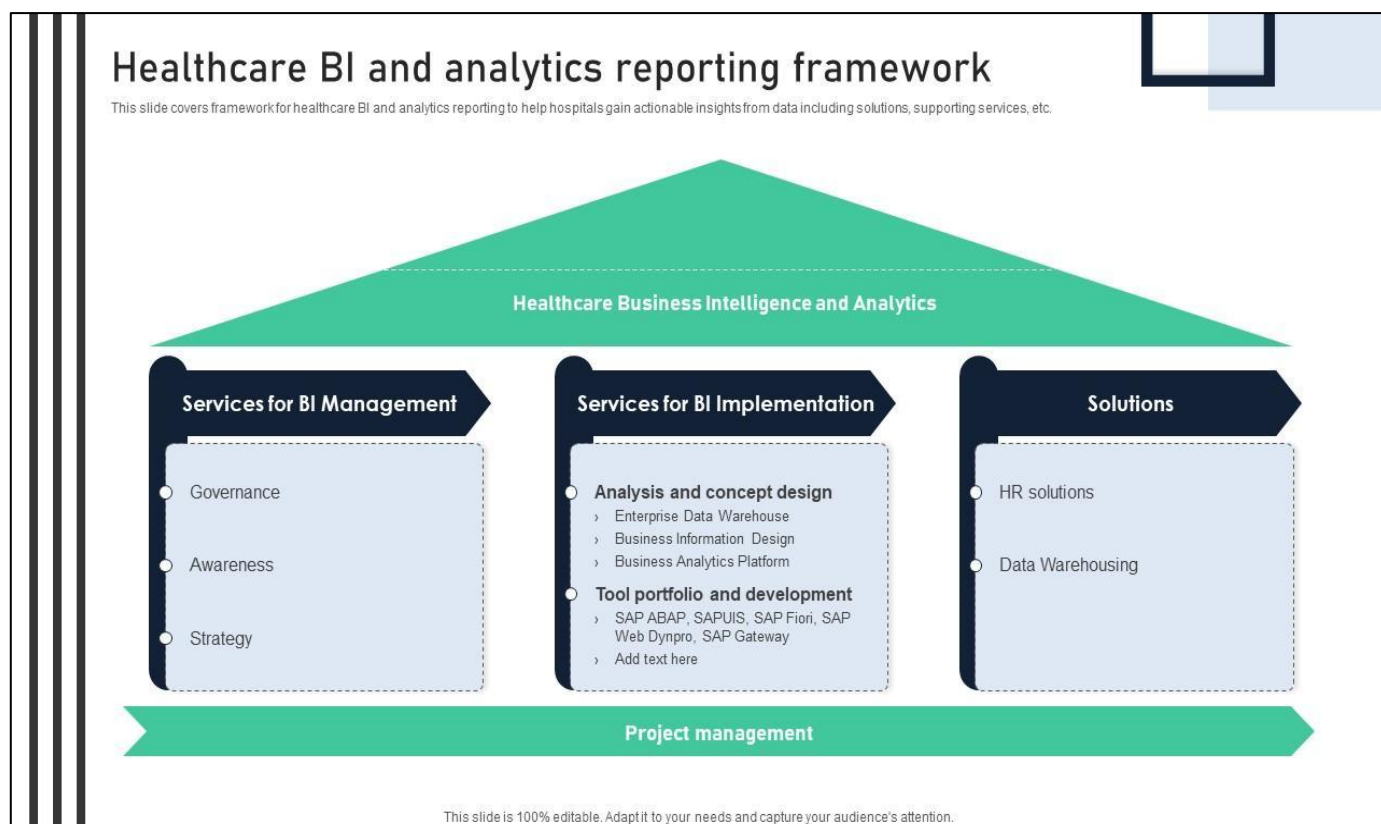


Fig 9 Representative Framework for Organizing Business Intelligence Management, Implementation, and Solution Services Under a Shared Project-Management Structure (Adapted from a Standard Business Intelligence Services Template; Original Source not Independently Attributable).

The project-management band under all three tracks in Figure 9 is not intended to be sequential, but rather continuous, in recognition that governance, technical implementation, and workforce solutioning cannot be sequential processes; a rural hospital that completes a technical implementation first and then moves on to governance and training is simply rolling top down through the same pattern that created the cultural resistance described in Section 8.4 (Barriers to Electronic Health Record Adoption: A Systematic Literature Review, 2016). Rural hospitals could use this type of parallel service tracks to define an internal project plan to address the barriers, instead of considering each barrier as a distinct problem to be solved individually.

The services taxonomy in Figure 9 is not meant to be taken literally as an organizational chart; a tiny rural hospital rarely has three distinct teams working on the management, implementation, and solutions tracks highlighted in the figure, and instead has a small team of individuals, as outlined in Section 8.3, responsible for each track. The requirement that each of these three tracks, and the project-management function linking them, must be given explicit ownership is what is preserved at this reduced scale, and the categories most apt to stall in implementation are those that are left without a named owner in Table 7.

Combined with the barrier categories listed in Table 7, Figure 9 also helps to answer a common question that often

arises in rural hospital leadership: what should be done first – governance or technical implementation? The parallel-track structure of the figure does not imply that the technical implementation track is supposed to come after the governance track; adoption research shows that for healthcare practitioners to overcome their resistance to new reporting

tools, it is necessary to make governance activities apparent before the technical implementation – for example, through governance chats that include a discussion of escalation procedures – and not only their technical sophistication (Healthcare Business Intelligence: Tools to Improve Patient Outcomes, 2024).

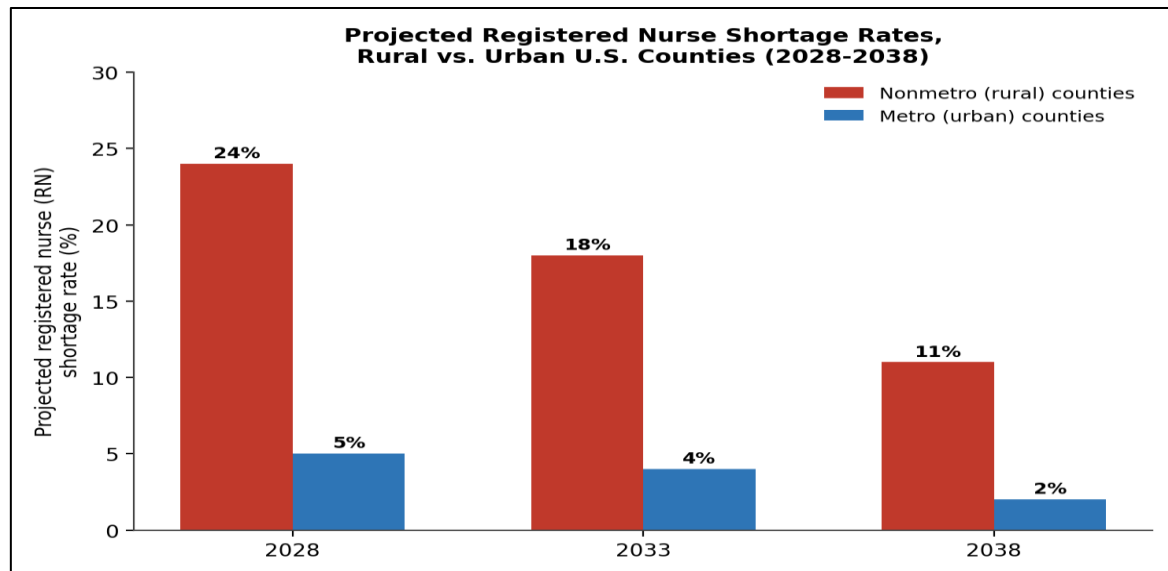


Fig 10 Projected Registered Nurse Shortage Rates, Rural vs. Urban U.S. Counties, 2028-2038 (Source: Rural Health Information Hub, 2026, citing HRSA Bureau of Health Workforce projections).

Figure 10 places the workforce challenges described in Section 8.3 in context with the national trend toward a greater proportion of registered nurse (RN) shortage counties in rural areas compared to urban areas over the 2028-2038 timeframe shown in the figure, with factors including an older rural nursing workforce, longer average commuting distances to training programs, and lower wages in rural counties relative to cost of living (Rural Health Information Hub, 2026; National Center for Health Workforce Analysis, 2024).

This projected shortfall is exacerbated by the nursing staffing challenge cited in this review, that a rural hospital is

struggling to keep the necessary number of nurses for direct patient care and a BI program relies on the same nurses to provide first-line quality control on patient data and to act when the dashboard alerts. As a result, facilities reporting difficulty maintaining safe nurse-to-patient ratios, the safety-margin indicator in Table 4, are the facilities least likely to be able to take on additional work related to analytics without dedicated staff, underscoring the need for the mitigation strategies outlined in Table 7 to take priority on protected role time rather than adding analytics responsibilities to an already full workload for existing staff members (National Rural Health Association, 2025).

Table 7 Barriers to Business Intelligence Adoption in Rural Hospitals, by Category, with Mitigation Strategies.

Barrier Category	Specific Barrier	Mitigation Strategy
Technical	Unreliable rural broadband connectivity	Prioritize on-premise/hybrid deployment where connectivity is unstable
Technical	Disconnected legacy source systems	Begin with Layer 1-2 data inventory before any dashboard purchase
Technical	Scarce informatics/IT staff capacity	Adopt low-maintenance platforms; consider shared regional IT support
Financial	Roughly 40% of rural hospitals lose money on patient services	Sequence low-cost/open-source tools before enterprise licensing
Financial	Limited capital competing with payroll and supplies	Pursue federal capital programs (e.g., USDA Community Facilities Program)
Workforce	No dedicated data analyst or informatics role	Assign BI ownership as defined, protected portion of an existing role
Workforce	Low baseline analytics literacy among staff	Favor low-learning-curve tools; invest training budget before tool cost
Cultural	Skepticism from prior difficult EHR rollouts	Start narrow-scope, visible quick-win dashboards before hospital-wide rollout
Cultural	Informal, relationship-based reporting norms	Introduce formal KPI governance gradually, with visible leadership use

The four barrier categories in Table 7 are ordered as a taxonomy, rather than a ranked list, because the evidence presented in Section 8 does not support using a single category as the dominant obstacle to implementing an HIT system; a well-capitalized rural hospital with good leadership sponsorship may encounter primary technical barriers, while a financially challenged hospital with skilled IT team members may encounter primary barriers related to finance and workforce, as documented in Sections 8.2 and 8.3, respectively.

The mitigation strategies listed with each barrier are intentionally ordered to be implementable without new capital where possible, including taking steps such as starting with a Layer 1-2 data inventory before purchasing any new dashboard, over strategies that require grant funding or a new hire. The sequence of these steps mirrors the same capital-focused design thinking that underpins the eighteen-month sequence proposed in Section 10, and will serve as a first step to help a rural hospital leadership team begin the process of mitigating barriers based on the type of barrier that's limiting their hospital's growth.

IX. BEST PRACTICE EXAMPLES AND IMPLEMENTATION CASE ILLUSTRATIONS

Although well-tested and peer-reviewed case studies of BI implementation within rural or CAH settings are still limited, there are a few documented healthcare BI deployments, which are summarized along with their transferable lessons in Table 9, that show design patterns a rural hospital might imitate at a smaller scale.

➤ *Surgical Service-Line Dashboard Case Illustration*

After a few fiscal periods of escalating surgical operating room costs without any case-level visibility into cost drivers, a two-hundred-twenty-bed community hospital in the Pacific Northwest launched a surgical business intelligence dashboard. The dashboard included case logs, case utilization, operating room staffing hours, and post-operative recovery time, and provided each surgeon with a personal dashboard view that compared his/her cases with other surgeons by procedure type, cost, and complication rate. After just the first review meeting (a KPI each month cantered on the dashboard), a twenty-two percent cost difference was identified between similar surgical cases (Leveraging Business Intelligence Dashboards for Real-Time Clinical and Operational Transformation in Healthcare Enterprises, 2025).

The takeaway from this for rural hospitals is not the particular surgical emphasis because many critical access hospitals don't have a full-service surgical department, but the design pattern, which involved a narrow-scope dashboard paired with a limited set of stakeholders and a regular, recurring meeting that led to insightful measures in a shorter time period than a hospital-wide dashboard rollout. Instead of attempting an all-department rollout in year one, a rural hospital might apply the same approach to its highest volume

service line, often the emergency department or a skilled nursing unit at the hospital's swing-bed, as a first BI project.

➤ *Emergency Department Flow Dashboard Case Illustration*

The same hospital case example also shows how an ED dashboard was implemented during the peak of the seasonal surge – like flu season – to prompt the ED staff to conduct pre-admission bed reviews sooner in the patient's visit, saving 2.4 hours per patient on average over the period of the study (Leveraging Business Intelligence Dashboards for Real-Time Clinical and Operational Transformation in Healthcare Enterprises, 2025). A 2.4-hour reduction is a significant proportion of the national median ED boarding time (now over 3 hours), and the mechanism of providing earlier access to surfacing bed-availability information to allow staff to intervene before a full ED bottleneck occurs is easily applicable to a rural ED, regardless of the size of the facility.

In the case of a rural hospital with a small ED and a relatively small number of beds, the flow dashboard would likely have to include real time status for swing beds, as well as conventional inpatient bed status, because the decision to convert an inpatient bed to a swing bed as described in Section 5.1 is a frequent rate-limiting step in acute patient flow within the rural context this review addresses, and is not as relevant in the larger urban hospital case example.

➤ *Population Health and Readmission Dashboard Case Illustration*

A third pattern that can be transferred to an integrated BI deployment in a large pediatric health system is one focused on population health rather than departmental flow. The system employed dashboards and predictive analytics to track patient flow, predict admissions and manage staffing, and for the chronic disease management outreach, it used the same data infrastructure, which has been linked to a readmission reduction of thirty percent and a twenty percent increase in chronic disease management outcomes (Garba et al., cited in The Role of Business Intelligence Tools in Improving Healthcare Patient Outcomes and Operations, 2024).

This is not a typical example for a typical size well-resourced paediatric system and the extent of improvement claimed is not necessarily representative of a smaller facility's technical capacity in a rural setting. The concept of a transferable design principle, however, of using the same integrated layer of data for both operational flow management and targeted clinical outreach, as opposed to building a separate, disconnected system for each of these purposes, is directly applicable within the five-layer framework proposed in Section 4, as a rural hospital's data integration layer (Section 4.2) is designed to provide these two uses from the same source of data.

Table 8 Domains and Example Indicators Used in Published Rural Hospital Financial Distress Models.

Domain	Example indicators	Reference
Financial performance	Profitability, uncompensated care, outpatient revenue share, CAHMPAS benchmark performance	Malone et al., 2025
Government reimbursement	Critical Access Hospital status, Medicare/Medicaid payer mix, Medicaid-to-Medicare fee index	Malone et al., 2025
Organizational traits	Ownership type, net patient revenue (size), health system affiliation	Malone et al., 2025
Market characteristics	Distance to nearest large hospital, local market competition	Malone et al., 2025; Holmes et al., 2017
Cost structure	Fixed-to-total cost ratio	Karim et al., 2026
Model performance (2025 update)	AUC = 0.87 on validation sample; four-tier risk classification	Malone et al., 2025

The six domains shown in Table 8 collectively identify the set of predictors behind the most recently validated rural hospital financial distress model with an area under the curve of 0.87 that classifies hospitals into four tiers of financial risk instead of a single binary at-risk designation (Malone et al., 2025). The fixed-to-total cost ratio domain, newly included in the last model update, was a finding that there is a correlation between the structural flexibility of rural hospitals to lower their cost base when patients fall, and the ratio of fixed costs to total costs (Karim et al., 2026).

The domains in Table 8 provide a practical way to begin to monitor financial risk internally within a rural hospital

building, even prior to a formal adoption of a predictive model: the market characteristics domain is a good reminder that financial risk measurement should consider a facility's location, not just the facility's own cost and revenue trends (Holmes et al., 2017).

- *Equation 4. Equity roll-forward relationship used in rural hospital financial distress modeling (Malone et al., 2025).*

$$Equity_{t+1} = Equity_t + NetIncome_{t+1}$$

Table 9 Documented Business Intelligence Dashboard Case Illustrations and Transferable Design Lessons for Rural Hospitals.

Case Setting	Dashboard Focus	Reported Result	Transferable Lesson
220-bed community hospital, Pacific Northwest	Surgical service-line cost and utilization	22% cost differential identified between similar cases	Narrow scope plus recurring review meeting drives insight
Same hospital, emergency department	ED flow and bed-availability visibility	2.4-hour reduction in average boarding time per patient	Early visibility into bed status prevents bottleneck formation
Large pediatric health system	Population health / readmission risk	30% reduction in readmissions; 20% improvement in chronic disease management	Shared data layer serves both flow management and clinical outreach
Multi-hospital secondary analyses (general)	Wait time, readmission, staffing utilization	Up to 35% wait-time reduction; ~20% readmission reduction; ~25% staffing efficiency gain	Effects concentrated where dashboards are embedded in workflow

The three case examples summarized in Table 9, although focused on different aspects of the clinical environment, have a common mechanism for achieving the reported improvements: each followed a narrowly scoped dashboard deployment, with a focused and recurring review meeting, but did not pursue a full-scale deployment of analytics across the enterprise (Leveraging Business Intelligence Dashboards for Real-Time Clinical and Operational Transformation in Healthcare Enterprises, 2025; Garba et al., as cited in The Role of Business Intelligence Tools in Improving Healthcare Patient Outcomes and Operations, 2024). This is the largest degree of overlap this review can demonstrate, without any published case studies available on the rural context, of the narrow-scope-first approach for implementation that the roadmap presented in Section 10 proposes.

The fourth row of Table 9 reflects the gains in wait time, readmission, and staffing efficiency reported in individual case examples, and this evidence appears to be representative

of the overall evidence of BI implementation: if dashboards are integrated or ashed into existing clinical and administrative workflows instead of functioning as a stand-alone reporting center, they can support a wide range of improvements in these areas. (Data-Driven Healthcare: The Role of Business Intelligence Tools in Optimizing Clinical and Operational Performance, 2025). This review returns to this point in Section 3.3, but none of the cases in Table 9 are from a place as small as a typical critical access hospital, and the size of the gains reported should be interpreted as a directionality not a certainty at rural scale.

X. A PROPOSED IMPLEMENTATION ROADMAP FOR RURAL HOSPITALS

This review recommends an eighteen-month implementation roadmap outlined in Figure 11, and detailed in Table 10, that will allow a rural hospital to implement BI capabilities incrementally and prove the value of the

implementation each step of the way before investing more capital or staff time in the next step.

➤ *Phase One: Data Foundation and Quick-Win Dashboards*

The first six months of the project should be dedicated exclusively to the data source and integration layers outlined in Section 4.1 and 4.2, with the first step being to create a full inventory of all existing data sources and a single, hospital-wide agreement on what each core metric, occupancy rate, ALOS, ED throughput and nurse-to-patient ratio means and how it will be calculated. Phase One should focus on implementing one or two “quick-win” dashboards that are designed around what the hospital considers its highest volume or most operationally painful surgical-service-line or ED-flow; rather than attempting to roll them out hospital-wide, they should be implemented in one of these areas first.

During phase one, the choice of platform should be decided in favour of the lowest cost option that is appropriate to the hospital's current technology stack, as it is the purpose of the first phase to demonstrate the benefit of the underlying data discipline and not to choose a permanent enterprise platform. If a hospital already has a Microsoft 365 environment, it is a good starting point to use the free version of Power BI Desktop; if a hospital has SQL skills in-house, it is a good starting point to have a self-hosted Metabase instance.

➤ *Phase Two: Integrated KPI Governance and Benchmarking*

Months seven through twelve should formalize what phase one demonstrated informally: a standing KPI governance committee, drawing from finance, nursing, and medical staff leadership, that reviews the dashboard on a defined cadence and has explicit authority to trigger the escalation pathways described in Section 4.4 when a metric crosses a predefined threshold. The external benchmarks should also link the hospital's internal KPIs to external

benchmarks including where applicable, the CAHMPAS national benchmarks referenced in Section 2.1 for critical access hospitals so that leadership can identify a metric that is trending in a negative direction from one that has crossed a national benchmark for risk (Malone et al., 2025).

The time is also right to broaden the data source scope and contents from quick-win departments to a hospital-wide perspective and to introduce the financial stressors (cost structure, payer mix and operating margin) described in Section 2.2 into the dashboard to begin to link the daily operational details with the hospital's trajectory of financial success and potential for survival.

➤ *Phase Three: Predictive and Prescriptive Analytics Maturity*

The most technical aspect of this project is in months 13-18 and only begins after weeks or months of staff engagement with phases one and two of the reporting system. Predictive models that are developed on top of a reporting system that is not reliable or being used are not likely to be useful. This stage will include forward-looking analytics such as length-of-stay and staffing-demand forecasting models like the ones described in Section 4.3 which are developed in the rural health services research literature (Malone et al., 2025; Holmes et al., 2017), and, if there's enough data history, an internally adapted version of the financial distress indicators developed in that literature.

Although a hospital with limited technical resources might never be able to construct a sophisticated, in-house predictive model, effective phase-3 value can be obtained by linking to external models that already exist; some of the financial distress models reviewed in Section 2.2 have been offered by the authors themselves as candidates for being hosted on external platforms that a rural hospital could subscribe to rather than develop.

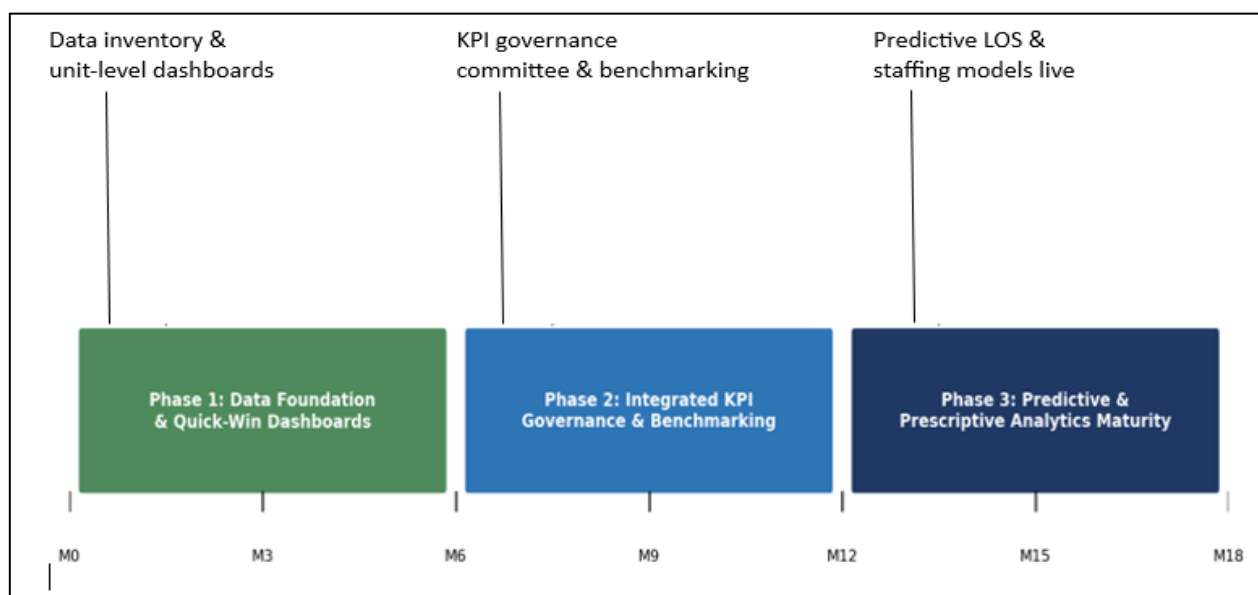


Fig 11 Three-Phase, 18-Month Business Intelligence Implementation Roadmap for Rural Hospitals (Original Framework Developed for This Review).

As shown in Figure 11, each phase is depicted in this document as a sequential block, and although the calendar months for each phase are shown, the actual boundaries between the phases are intended to be flexible rather than fixed to the calendar months indicated, such that a hospital that has not yet achieved sustained staff engagement with its phase one dashboards, the entry condition described in Section 10.3, should extend phase one rather than advance to phase two simply because six months has passed.

The roadmap in Figure 11 intentionally prioritizes activities and data inventory that require little capital and are high on the probability of success—before making investments in governance and predictive-analytics capabilities outlined in Table 10—reflecting the researchers' preference for an incrementally deployable, real-time early-warning capability over one large model that is built and validated prior to any use in practice (An Updated Model of Rural Hospital Financial Distress, 2025).

Table 10 Proposed Three-Phase, Eighteen-Month Rural Hospital BI Implementation Roadmap.

Phase	Timeframe	Primary focus	Key deliverables
Phase 1	Months 0-6	Data foundation & quick-win dashboards	Data-source inventory; unified KPI definitions; 1-2 department-level dashboards
Phase 2	Months 7-12	Integrated KPI governance & benchmarking	Standing governance committee; escalation protocols; CAHMPAS/national benchmarking
Phase 3	Months 13-18	Predictive & prescriptive analytics maturity	LOS/staffing forecasting models; adapted financial distress monitoring

The eighteen-month schedule in Table 10 is a minimum viable schedule, not an exhaustive list; it might be possible to condense the eighteen-months in a hospital with an unusually competent IT function, and it may take more than six months to complete the phase-one data inventory in a hospital just starting the technical and cultural barrier mitigation tasks described in Section 8.

The phase-two deliverables in Table 10 also include linking internal KPIs to CAHMPAS and other national benchmarks, making it a natural checkpoint for a rural hospital's BI program to be visible to, and useful for, the kind of federal capital-program applications discussed in Section 8.2, as documented linkages to recognized rural hospital benchmarks enhance a funding application in ways that internally defined metrics alone cannot (USDA ERS, 2025).

XI. DISCUSSION

➤ *Correlating BI Maturity With Financial and Clinical Performance*

The findings in this article, although drawn from health systems much larger than the typical rural hospital, align on a common theme: measurable operational improvement tends to be more reliably achieved by making sure the data the health system has on its BI platform is accurate and trusted than by any other characteristic of the BI platform, other than ensuring there's a specific governance process in place that links that dashboard to a real decision. The surgical, emergency department, and population health case illustrations in Section 9 all resulted in the reported improvements because of the same characteristics: a limited initial focus, a clear, recurring review process, and a clear owner who's responsible for taking action on the data he or she sees—rather than any specific proprietary features of the vendor.

The pattern has implications for the way rural hospital leaders should consider the connection between BI maturity and financial distress indicators discussed in Section 2.2. That a fixed-to-total cost ratio is declining, or that a contingent-labor share is increasing, as reported in a dashboard, Section

5.4, doesn't provide any protection, unless it is part of a governance process that has the authority and the means to take action in a timely manner well before the ratio is reported in an annual cost report – the entire idea behind the staged roadmap in Section 10 is that governance capability, rather than software capability, is the limiting factor on whether or not BI implementation improves a rural hospital's trajectory.

➤ *Policy Implications for Federal and State Rural Health Programs*

There are many data sources that already exist that a rural hospital BI framework would need, such as CMS cost reports, CAHMPAS benchmarks, and AHA IT supplement surveys, but they are not well-connected to the operational dashboards that rural administrators would use to act on them. Similarly, the logic of the USDA Community Facilities Program finding that survival probability of rural hospitals is correlated with USDA funding for technology could be applied to future investments in rural hospital support through technology, which might be contingent in some way on the capacity-building of BI or analytics.

The high cost of advanced health information technology functions documented in Section 2.3 further indicates that the narrow attention of early federal investment programs, including the HITECH Act, on advanced health information technology functions related to basic EHR adoption is being seen as a case of diminishing returns, as adoption of basic EHRs has become nearly universal, while the advanced interoperability and analytics functions that form the backbone of BI remain unevenly distributed (The Digital Divide in Adoption and Advanced Use of Electronic Health Records Among US Hospitals, 2026). To further reduce this rural-urban technology disparity, incentives to promote the capabilities of analytics may be necessary in the future instead of incentives for EHR adoption.

XII. FUTURE RESEARCH DIRECTIONS

➤ *Development of Low-Cost Analytics Tailored to Critical Access Hospitals*

The cost comparison of the BI tools in Section 7 was based on the general purpose of the platforms—not on any specific tool designed for critical access hospital operations. A second area of future research and development that would be useful to a critical access hospital is the creation of a stripped-down, CAHMPAS-aligned analytics template, pre-configured with the standard KPI definitions described in Sections 5 and 6, that a CAH could deploy on a free or low-cost open-source platform without having to design its own data model from scratch, thus reducing the implementation barrier described in Section 8.1.

➤ *Integration of Predictive Closure-Risk Models Into Operational Dashboards*

While the financial distress models that were reviewed in Section 2.2 demonstrated good predictive performance (area under the curve of 0.87 in the latest validated model), they also were academic research products and not tools that could be integrated into the operations of rural hospitals. The financial distress models reviewed in Section 2.2 had good predictive performance (area under the curve of 0.87 in the latest validated model), but they were also academic research products, rather than tools that could be integrated into the operations of rural hospitals. The development and possible validation of an ongoing version of this model to be embedded into a rural hospital's dashboard, so that the hospital's leadership could see the trajectory of risk of financial distress, along with the hospital's operational KPIs, as they saw it in the moment, rather than only realizing the

hospital's elevated risk after it was published by an outside academic group periodically, as has already been called for in this literature; (An Updated Model of Rural Hospital Financial Distress, 2025).

➤ *Multi-Site Benchmarking Consortia for Rural Hospital Systems*

The statistical stability limitation discussed in Section 6.3 for patient safety indicators is applicable in a general manner to all of the rural quality metrics. One potentially very fruitful area of research is the development of formal data-sharing consortia of many small rural hospitals that could be organized through existing state Flex Program offices or regional rural health associations, and from which each small hospital could derive its benchmarking from a statistically relevant peer group of rural hospitals instead of a national average of many large urban hospitals.

➤ *Artificial-Intelligence-Augmented Decision Support for the Rural Workforce*

Furthermore, future research should explore whether natural-language and generative artificial intelligence interfaces, which are growing in many commercial BI tools described in Section 7.1, can help successfully reduce the analytics-literacy barrier that need be overcome to interact productively with a hospital dashboard, such as when a charge nurse asks a simple question like "What is the staffing ratio tonight?". There is an open and practically relevant research gap in the rigorous evaluation of these new kinds of natural language BI interfaces, which is not yet assessed through general-market vendor claims, but specifically in the context of rural environments.

Table 11 Summary of Proposed Future Research Directions in Rural Hospital Business Intelligence.

Research Direction	Core Gap Addressed	Potential Method
CAHMPAS-aligned low-cost analytics template	High implementation barrier for smallest CAHs	Open-source platform pre-configured with standard KPI library
Dashboard-embedded closure-risk prediction	Financial distress models remain academic, not operational	Prospective validation of a continuously updated risk score
Multi-site rural benchmarking consortia	Low statistical stability of single-facility rural metrics	Regional data-sharing agreements via Flex Program offices
AI-augmented natural-language decision support	Low analytics literacy among overextended rural staff	Rural-specific evaluation of conversational BI interfaces

The four research directions outlined in Table 11 all have a focus on bridging the gap between research that is proven at a larger health system size and that which has not been proven at the rural or critical access hospital level, either in terms of tool cost, model deployment, statistical sample size, or staff analytics literacy.

The research direction outlined in the cells of Table 11 would be most likely to accelerate the adoption of rural BI if pursued simultaneously, compared to being pursued in isolation, because following one of the directions would directly add to the statistical basis for the dashboard-embedded closure-risk models outlined in the same table, and a validated low-cost analytics template would provide any resulting benchmarking consortium with a common technical platform on which to build (Malone et al., 2025).

XIII. CONCLUSION

For the past many years, the U.S. rural hospital closure and financial-distress trend steadily have been getting worse — and it's not slowing down now — with almost 700 rural hospitals now listed at risk for closure and approximately one-third operating at a financial loss overall, even as financial aid from the pandemic has ceased (Becker's Hospital Review, 2026). This review has been arguing that business intelligence, when designed as a five-layer approach that starts with data sourcing, data integration and data governance, data analytics, data visualization and data-to-decision-action, provides a realistic and incremental deployment approach for rural hospitals to gain more value from the operational data they currently collect, rather than a

massive enterprise-scale technology investment that most rural facilities can't afford.

The operational and clinical KPIs looked at in Sections 5 and 6 – namely bed occupancy, average length of stay, emergency department throughput, staffing ratios, readmission rates, obstetric and patient safety indicators – are not 'exotic' or difficult to define – the real difficulty has been the lack of infrastructure, finance and cultural buy-in to collecting them consistently across rural zones. This reality is at the centre of the 18-month roadmap that has been proposed in Section 10 (phased), with the rapid-win dashboards and governance programs ahead of the formal governance and predictive analytics processes so that a rural hospital can develop sustainable capacity and capability rather than an abandoned pilot project.

Ultimately, evidence gathered here indicates that simple EHR incentive programs will likely not do enough to close the rural-urban health information technology and analytics adoption gap, as simple adoption has almost reached the point of being universally adopted while advanced use of analytics remains highly unequal (The Digital Divide in Adoption and Advanced Use of Electronic Health Records Among US Hospitals, 2026). To close this gap, however, will take a mindful mix of low-cost or open-source tooling, phased implementation discipline and targeted federal and state policy support for building analytics capabilities – an agenda this review has tried to make real rather than idealistic.

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