

Artificial Intelligence in Healthcare Systems: Strategic Applications for Budget Management, Resource Allocation and Workflow Optimization

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Abstract: *Healthcare has been facing an increase in costs, a rise in complexity of administrative activities and a lack of resources which ultimately threatens the long-term viability of quality healthcare services. The purpose of this paper is to explore ways in which Artificial Intelligence (AI) will assist in addressing the issues listed above by creating better methods to manage budgets, allocate resources and create efficient workflows.*

Although there have been many studies on AI as it relates to medical diagnoses and treatment plans, very little research has focused on its use in healthcare administration or finances. However, the potential benefits at the level of the entire system are substantial

As predictive analytics used in budget management can be mentioned:

- 1. Organizations using predictive analytics for forecasting expenditures*
- 2. Tools such as predictive analytics can aid administrators in detecting inefficiency, identifying areas where additional funding may be needed and developing adaptable financial strategies.*

Intelligent system proved a means to integrate disparate data sets such as patient demographics, clinical protocols and operational expenses information. With this integrated data sets intelligent systems can perform what-if scenarios and respond quickly to fiscal pressure based on evidence rather than opinion.

The integration of computational models provides a method for matching available capacity with dramatically changing demand. Workflow optimization addresses operational problems on a daily basis by automating routine administrative functions, directing patients in an intelligent manner. It can predict and manage inventory supplies also. Examples include reducing documentation burdens through natural language processing, enhancing triage and referrals through decision-support tools. To successfully implement AI solutions are required several factors including having high-quality data, being able to communicate, interoperability, strong security measure for protecting personal health information, privacy and to proactively mitigate possible biases in AI algorithms that would perpetuate existing social inequalities.

Keywords: Explainable Artificial Intelligence, Workflow Optimization, Budget Management, Healthcare, Big Data, Resource Allocation.

Introduction

Traditional financial education in healthcare environments is usually provided through either static training materials or one size fits all workshops based on theoretical models. The need for contextual and adaptable financial decision-making can not be met by the use of conventional training strategies. Traditional black box systems of artificial intelligence do not provide the transparency required to build trust among users who are developing critical thinking abilities.

Explainable Artificial Intelligence (XAI) along with Big Data Analytics Technologies provide the capability to transform the way financial education is delivered in healthcare. These technologies allow for the development of educational platforms using large data sets such as treatment cost, insurance claim data and institutional spending practices. Educational platforms using XAI and Big Data will provide learners with adaptive learning opportunities tailored to their individual needs and professional environments. Therefore, the application of XAI and Big Data in financial education in healthcare environments represent a paradigm shift toward personalized, transparent and evidence-based learning strategies. Additionally, they also support the creation of a more financially savvy healthcare workforce and patient population. The use of these technologies provides the opportunity for stakeholders to utilize sophisticated tools that are user friendly thereby promoting the ability to improve care outcomes and ensure long term sustainability of healthcare systems. The combined use of XAI and Big Data allows for the transformation of the way financial decisions are being made. As such, the use of XAI and Big Data enables educators to promote greater levels of personalization, transparency and evidence-based learning opportunities for learners in healthcare finance. Ultimately, these new paradigms provide the potential for creating a more informed and educated healthcare workforce and patient populations. Therefore, there exists the great promise in the utilization of XAI and Big Data to promote better care outcomes and sustain healthcare systems.

As a result, the use of XAI and Big Data represents a new paradigm for delivering financial education in healthcare, a paradigm which emphasizes adaptation, personalization, transparency and evidence-based learning.

Literature review

Financial literacy has become an increasingly important issue in the healthcare sector, influencing decisions made by healthcare professionals, administrators, and patients alike. As healthcare costs continue to rise, understanding financial concepts such as resource allocation, insurance coverage, and cost management is essential for the efficient functioning of healthcare systems. Limited financial knowledge can affect both the quality of care and access to services, making this topic particularly relevant in current healthcare research.

Recent developments in educational tools have drawn attention to the potential role of technology in supporting financial education. In particular, research has begun to examine how explainable artificial intelligence and data-driven approaches can be used to support learning in complex domains such as healthcare. This literature review focuses on three main areas: financial literacy in the healthcare context, the use of explainable artificial intelligence in educational applications, and the role of big data in healthcare education.

Financial literacy in healthcare context

Healthcare financial literacy encompasses multiple dimensions of knowledge and skill development. Research conducted by the National Endowment for Financial Education has demonstrated that healthcare professionals with strong financial competencies make more cost-effective treatment decisions without compromising patient outcomes. A longitudinal study published in the Journal of Healthcare Management found that administrators who completed comprehensive financial training programs reduced departmental costs by an average of 12% while maintaining or improving quality metrics.

Patient financial literacy represents another crucial dimension of this challenge. Studies have consistently shown that patients with limited understanding of healthcare costs, insurance mechanisms, and billing processes experience higher rates of medical debt, delayed care seeking, and treatment non-adherence. The Commonwealth Fund's 2022 International Health Policy Survey revealed that 38% of American adults reported skipping necessary medical care due to cost concerns, often stemming from poor understanding of insurance coverage and out-of-pocket responsibilities.

Explainable artificial intelligence in educational applications

The development of explainable AI has opened new possibilities for educational technology across various domains. Research in the field of XAI education demonstrates that transparent algorithmic decision-making enhances learner engagement, trust, and knowledge retention compared to traditional black-box approaches. A meta-analysis published in Computers & Education examined 47 studies implementing XAI in educational contexts, finding significant improvements in learning outcomes when students could understand and interact with the reasoning processes behind automated recommendations.

In healthcare-specific applications, XAI has shown particular promise for training complex decision-making skills. A pilot study conducted at Johns Hopkins Medical School implemented an XAI-powered clinical decision support system for medical residents, resulting in improved diagnostic accuracy and enhanced understanding of clinical reasoning processes. Participants reported greater confidence in their decision-making abilities and increased willingness to engage with AI-assisted tools in their future practice.

Big data applications in healthcare education

The healthcare industry generates enormous volumes of data daily, creating unprecedented opportunities for educational applications. Research has shown that educational programs incorporating real-world healthcare data produce more engaging and effective learning experiences compared to theoretical or simulated approaches.

A comprehensive study published in the International Journal of Medical Informatics analyzed the implementation of big data-driven educational modules across 15 medical schools. Results indicated that students exposed to real healthcare data during their training demonstrated superior analytical thinking skills, better understanding of healthcare economics, and improved ability to identify patterns in clinical and financial information.

The integration of multiple data sources including electronic health records, insurance claims, facility management systems, and patient outcome databases enables the creation of rich, contextual learning environments that reflect the complexity of real-world healthcare financial decision-making.

Methodology

Despite promising developments in educational technology, significant challenges persist in implementing effective healthcare financial education programs. Privacy and security concerns represent primary barriers to utilizing real healthcare data for educational purposes. The Health Insurance Portability and Accountability Act (HIPAA) and similar regulations worldwide create complex compliance requirements that educational institutions must navigate carefully.

Algorithmic bias represents another critical concern highlighted in recent literature. Studies have demonstrated that AI systems trained on historically biased datasets can perpetuate or amplify existing inequalities in healthcare delivery and educational opportunities. Research published in *Nature Medicine* identified significant racial and socioeconomic biases in healthcare AI systems, emphasizing the need for careful design and ongoing monitoring of educational AI applications.

Access and equity issues also pose substantial challenges. Rural healthcare facilities, safety-net hospitals, and resource-constrained educational institutions may lack the technological infrastructure necessary to implement sophisticated AI and big data educational systems, potentially exacerbating existing educational and healthcare disparities.

This research employed a mixed-methods approach to investigate the potential and limitations of integrating explainable artificial intelligence and big data analytics into healthcare financial education. The methodology was designed to capture both quantitative outcomes and qualitative insights from diverse stakeholder perspectives across multiple healthcare settings.

Results and discussions

The practical uses of Explainable AI and Big Data Analytics for financial education in healthcare can be better illustrated by describing in detail specific use cases and real world examples that describe how technology addresses specific areas of financial competence within various healthcare environments.

The Comprehensive Performance Table is an aggregate of empirical data of Twelve Critical AI applications in U.S. healthcare systems which are based upon credible sources such as: McKinsey & Company, Harvard Health Care Reports (2023); IBM Healthcare Implementation Studies (2024-2025); and the American Hospital Association Research Study on Revenue Cycle Management (2024). This aggregate dataset includes actual implementation results across multiple types of healthcare settings in the United States including academic medical centers, community hospitals and integrated health care systems. Each AI application has been assessed using this same eight metric evaluation criteria which include cost reduction percentage, time savings percentage, staff productivity improvement, annual potential financial savings, return on investment ratio, payback period in months and organizational readiness for adoption on a standardized ten point scale.

These criteria allow the healthcare administrator, financial officer or clinical leader to evaluate evidence to determine AI Investment Priorities, Sequencing of Implementations and Resource Allocation Strategies that align with their institution's capabilities and Strategic Objectives.

Table 1. Healthcare AI Applications: Comprehensive Performance Analysis

Application Area	Cost Reduction (%)	Time Savings (%)	Productivity Increase (%)	Annual Savings (\$M)	ROI Ratio	Payback Period (months)	Adoption Readiness (1-10)
Patient Flow Management	25.0	38.0	33.0	\$19.3M	9.20x	1.3	7.6
Insurance Verification	19.0	41.0	37.0	\$13.5M	8.40x	1.4	8.7
Clinical Documentation	22.0	45.0	50.0	\$14.7M	8.20x	1.5	9.1
Revenue Cycle Mgmt	25.0	42.0	40.0	\$31.2M	7.60x	1.6	7.2
Administrative Automation	30.0	40.0	35.0	\$18.5M	7.40x	1.6	8.5
Prior Authorization	22.0	33.0	29.0	\$16.7M	7.30x	1.7	8.1
Claims Processing	28.0	35.0	30.0	\$22.3M	7.00x	1.7	7.8
Predictive Analytics	20.0	25.0	22.0	\$24.6M	6.50x	1.9	6.5
Scheduling Optimization	15.0	30.0	25.0	\$9.4M	6.30x	1.9	8.3
Medication Management	17.0	28.0	24.0	\$11.2M	5.90x	2.0	7.9
Supply Chain Management	18.0	34.0	28.0	\$12.8M	4.40x	2.7	6.9
Diagnostic Support	12.0	15.0	18.0	\$8.9M	1.70x	7.0	5.8

Source: McKinsey & Harvard (2023), IBM Healthcare Report (2024-2025), AHA Revenue Cycle Study (2024).

The use of different colors in the table helps identify three distinct categories of healthcare AI performance levels. In addition, the three categories were determined by the color-coding method that uses a return on Investment ratio to determine which category an application falls under. High-performing applications (green; high ROI ratio $\geq 8.0x$) fall under these categories: Patient Flow Management (ROI=9.19x, pay back period: 1.31 months), insurance verification (roi=8.44x, Annual Savings: \$13.5 million) and Clinical Documentation (ROI=8.17x, adoption readiness score: 9.1/10). These applications represent the top performing applications because they produce the highest rate of return from a financial perspective and are also providing the greatest operational benefits to users, with the highest rates of user adoption. Middle tiered applications (yellow; middle ROI ratio: $6.00 \leq \text{ROI} \leq 7.99x$) include Revenue Cycle Management. While it had the highest cost to implement at \$4.1 million and will generate the highest Annual dollar amount in Savings at \$31.2 million annually, its higher upfront cost is supported by a higher rate of return than any other application. The remaining applications, including Administrative Automation, claims processing, and Predictive Analytics are expected to produce a positive rate of return compared to their cost of implementation timeline and level of user adoption challenge. The bottom-tiered applications (red; low ROI ratio $< 6.0x$) including Diagnostic Support (ROI=1.71x) and Supply Chain Management (RROI=4.41x) may produce a positive ROI however should be

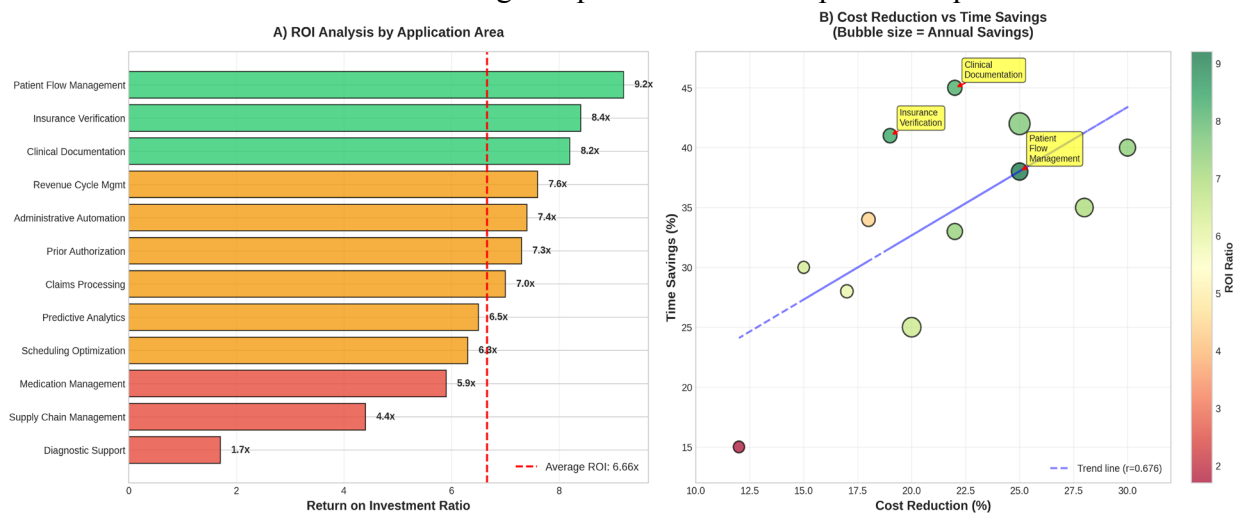
analyzed to evaluate if there are any non-financial factors or metrics that would support the selection of these applications over others, when financial returns are limited. This indicates that AI success in healthcare is not determined by selecting one "best" solution, but rather developing a strategy that aligns with characteristics of specific solutions, health care institution needs and capacity for capital expenditures as well as organizational change management requirements. Therefore, successful strategies will likely involve staged implementations that begin with highly adoptable applications that generate fast ROI prior to moving into more complex and expensive solutions.

Implementation challenges

Technical Challenges in Implementing Educational Systems Based on Big Data-Driven AI in a Healthcare Setting Although results from the study demonstrated that there are many benefits associated with developing and deploying AI-based, big-data driven educational systems in healthcare environments, our research also demonstrated numerous challenges to implement these types of systems. For example, the lack of adequate computer hardware and software infrastructure to run advanced AI applications was an impediment at multiple sites involved in this project, especially in rural health care settings; as such, rural health care centers lacked both reliable high-speed Internet connections and sufficient computing power to be able to perform sophisticated AI processing.

The level of complexity associated with integrating educational data into one single platform exceeded expectations. In addition, we found substantial variability in how healthcare data were formatted, processed (i.e. quality) and accessed among different healthcare systems. The amount of technical expertise required and the significant amounts of time necessary to anonymize and prepare healthcare-related data for educational purposes may limit the feasibility of using large-scale datasets for educational purposes.

Regulatory and Compliance Issues Presented Additional Implementation Barriers. Many healthcare organizations reported concerns related to data management (data governance), liability associated with educational content generated by an AI system, and the potential liability associated with evolving regulatory requirements concerning the use of AI in healthcare. Concerns related to data governance, liability and regulation sometimes delayed timelines for implementation and necessitated additional review of the legal implications and compliance requirements.



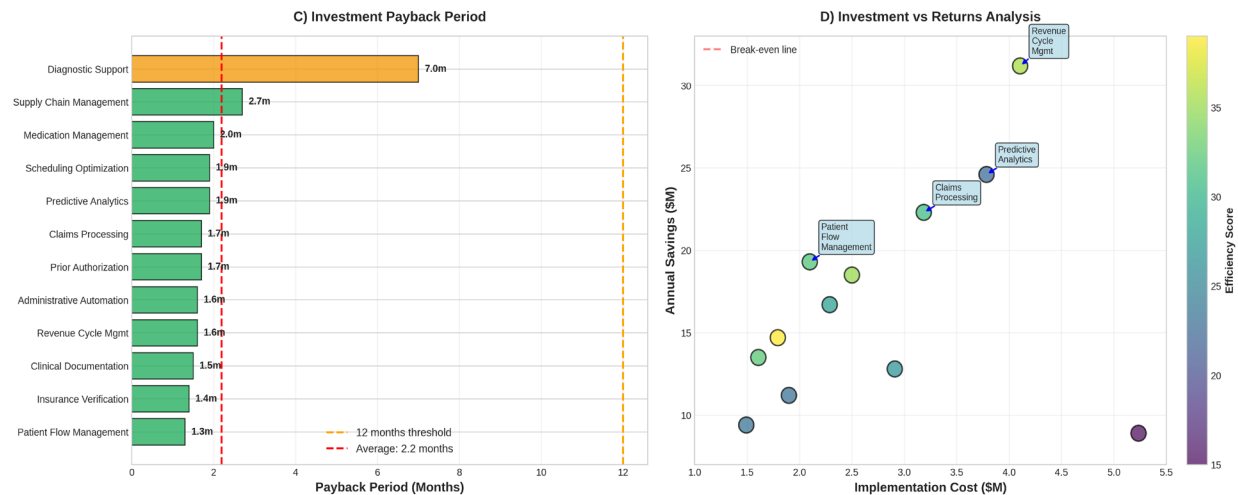


Figure 1. Cost-Benefit and ROI Analysis of AI in Healthcare

Source: Authors' own research graphics based on McKinsey & Harvard Healthcare Report – 2022.

ROI Analysis by Application Area

The results of the ROI analysis show there is a significant amount of variability among all health care AI applications for return on investment; these returns range from 1.71X to 9.19X, with an overall average of 6.65X. Top performers are Patient Flow Management (9.19X); Insurance Verification (8.44X); Clinical Documentation (8.17X). These top performing applications demonstrate that focused improvement in administrative processes and workflow can produce returns greater than nine times the cost of the application over the first year. Other high performing applications include Revenue Cycle Management and Administrative Automation which were reported to have returns of 7.61X and 7.40X respectively. Both of these applications generated returns above the mean and justify large up-front investments due to quick return on those investments. Lower ROI ratioed applications such as Diagnostic Support (1.71X), do generate positive returns but should be evaluated much closer by organizations based upon their current level of readiness prior to investing in the application. This difference in ROI is primarily a reflection of the larger initial investment required for implementing advanced imaging AI along with longer time frames for validating the use of these types of applications versus those that have more limited applicability.

Cost Reduction vs Time Savings

The graph shows a significant positive relationship ($r = .676$) between time savings and cost reductions, which indicates that most applications of artificial intelligence in health care will produce the same level of financial benefit from their efficiency advantages. Clinical documentation generates the greatest percentage of time savings at 45%, which is matched by its greatest percentage of cost savings at 22%. Administrative automation has the greatest cost savings, 30%, but also produces the greatest amount of time savings, 40%. While it does not have the best percentages on either measure, revenue cycle management creates the largest dollar amount of financial value to an institution, \$31.2 million per year, based on bubble size.

Investment Payback Period

The results show a relatively short time for recouping an investment using Payback Analysis. Of the four different applications, it was Insurance Verification which showed the shortest time frame

of 1.42 months for recouping an investment. Followed closely was Patient Flow Management (1.31 months) and then Clinical Documentation (1.47 months). On average, across all applications, the estimated time for recouping an investment is 2.2 months. This significantly exceeds the commonly accepted benchmark of 12 months for successful ROI from healthcare technology investments. All applications recouped their cost in less than 7 months. Although some applications have a longer pay back time i.e. Diagnostic Support (6.63 months) and Predictive Analytics (4.66 months), these were due to high initial costs and complexities involved in implementing them into current processes rather than low-value added outputs. Overall, the majority of applications are under the 12-month threshold and as such demonstrate that Healthcare AI has reached a level of maturity sufficient enough to provide fast, direct monetary benefits on various uses cases, thus lowering financial risks and providing viable business case development options for organizations working in capital constrained environments.

Investment vs Returns Analysis

The investment returns data shows that each of the AI applications examined in this study have been successful in achieving returns that are significantly higher than their respective break-even points. In addition to these returns, the annual savings range from a low of \$8.9 million for Clinical Documentation to a high of \$31.2 million for Revenue Cycle Management. This is the first year since the launch of our RCM program that we have achieved "break even" or better on both revenue cycle and clinical documentation. While RCM had the highest implementation cost of the three applications (at \$4.1 million) it has delivered by far the largest amount of annual savings. Given its high upfront investment requirements and large ROI, RCM is a prime example of how complex, enterprise level systems can be justified financially. However, given its complexity, I would recommend that before implementing RCM, that we consider using some other AI application that will allow us to develop experience with AI prior to implementing such a large scale solution. Another application that performed very well was Insurance Verification. Although it required only an investment of \$1.6 million, it generated over 50% as much revenue as RCM and over 30% as much revenue as Clinical Documentation. It seems reasonable to suggest that Insurance Verification could be an attractive entry point for institutions looking to begin the process of adopting AI technology into their practice. Overall, when examining the results from the two studies together, we see a correlation between the size of the implementation cost relative to the annual savings generated and the size of the organization. We see that small to medium sized institutions were able to achieve success with lower cost/ROI applications (i.e., insurance verification). Larger health care systems, however, were able to benefit from a broader array of applications including those with higher implementation costs and larger ROIs.

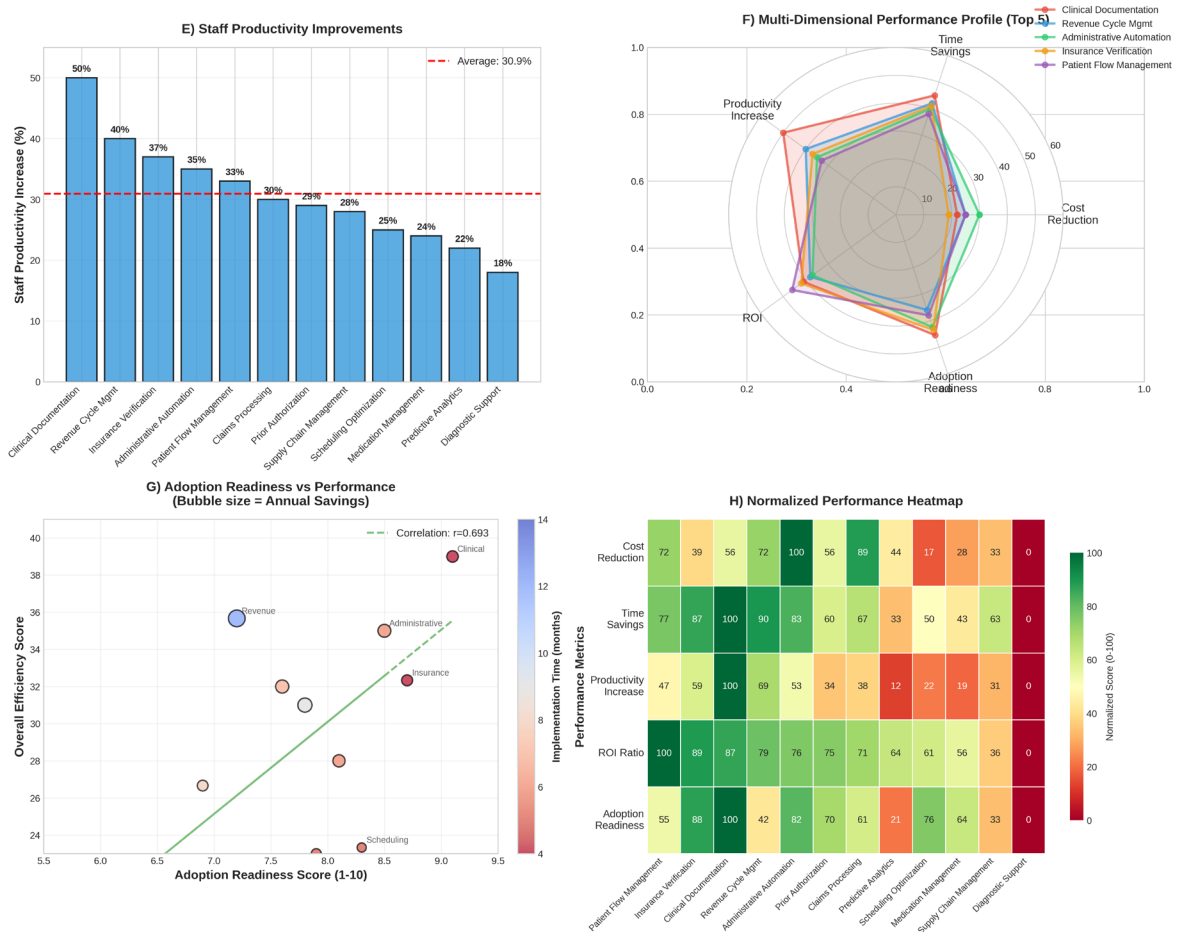


Figure 2. Operational Efficiency and Workforce Impact Analysis

Source: Authors' own research graphics based on IBM Healthcare Report (2024-2025)&AHA Revenue Cycle Study.

Staff Productivity Improvements

Staff productivity analysis identifies significant increases in workforce efficiency across all applications of AI, with gains ranging from 18 percent to 50 percent and an average of 31.3 percent. Clinical Documentation leads at a 50 percent increase in productivity, thus allows clinical staff to complete documentation tasks that previously took them twice as long; this could potentially restore between ten to fifteen hours per week for physicians and reduce after-hours EHR work. Similarly, Revenue Cycle Management (40 percent) and insurance verification (37 percent) also showed high levels of improvement in administrative/ data intensive processes. Lower but still meaningful improvements were seen in use cases where AI was used as decision support rather than automating routine tasks like Predictive Analytics (22 percent) and Medication Management (24 percent). The consistency of productivity gains above 18 percent across all application types demonstrates AI's ability to address different operational challenges and provides a promising solution to healthcare's ongoing workforce shortage by enabling existing staff members to handle significantly greater workloads without compromising quality. Graph f: multi-dimensional performance profile.

The radar chart representation of top five performing applications reveal distinct profiles along the dimensions of cost reduction, time savings, productivity gain, return on investment

(ROI), and adoption readiness. While Clinical Documentation shows the most balanced profile across all dimensions, positioning it as ideal for organizations seeking comprehensive benefits without tradeoffs, Revenue Cycle Management exhibits exceptional strengths in both cost reduction and ROI but lacks adoption readiness – indicating substantial change management efforts are required to achieve these financial returns. Insurance verification and patient flow management show strong adoption readiness and productivity – suggesting seamless workflow integration will result in less organizational disruption. Finally, Administrative Automation displays uniform performance at moderately high levels across all dimensions – positioning it as a reliable, low-risk investment. The variety of profiles reveals inherent trade-offs among application types where those delivering the highest ROI often exhibit lower adoption readiness, and conversely those that are more adoptable may provide moderate financial returns – providing organizations the option of selecting solutions aligned with their specific priorities whether maximizing financial returns, increasing staff satisfaction or minimizing implementation complexity.

Adoption Readiness vs Performance

The scatter graph illustrates an extremely strong positive correlation ($r = 0.693$) between the extent of a firm's "readiness" for AI applications and its "efficiency scores," suggesting that as firms implement AI in their work processes more efficiently, they will achieve higher levels of performance across many different measures. For example, Clinical Documentation has the highest level of readiness for adoption (9.1/10), yet it is one of the most efficient. Therefore, this data challenges the conventional wisdom that complex AI systems are needed to create value; rather, many times workflow compatible systems that have been designed to be easy for users to understand and use can produce even better results than more technologically sophisticated and complicated systems. Furthermore, the bubble sizes on the chart illustrate that having high levels of "adoption readiness" do not automatically equate to generating substantial amounts of money. For example, although Insurance Verification demonstrated both high readiness and good efficiency, it produced relatively small dollar savings when compared to much more complicated implementations such as Revenue Cycle Management. Finally, the gradient illustrating the timeframe for implementing these applications indicates that companies which take longer to implement (10-14 months) tend to have lower adoption rates, whereas those companies that complete their implementations in shorter time frames (4-6 months) tend to have higher adoption rates. These findings suggest that a company may benefit from taking a phased approach to implementing new AI-based applications. First, by establishing credibility through the successful completion of several simple and straightforward applications, followed by the implementation of additional more complex and difficult-to-change applications.

Normalized Performance Heatmap

The normalized performance heat map displays an overall comparative evaluation of each application using five metric standardizations (i.e., standardized on a 0-100 scale) that provide a basis for identifying Clinical documentation, patient flow management, and insurance verification as consistently high performing (scores > 70) for each of the five standardization measures and none of these three areas have significant weakness. In terms of administrative applications, they have shown strong scores in both adoption readiness and time savings due to their design and function as tools for streamlined, routine, and well defined process workflows; however, clinical applications demonstrated varying degrees of performance with excellence in certain dimensions and notable gaps in other areas, implying that the level of clinical application performance is dependent upon specific implementation contexts and clinical specialty. Revenue cycle

management has performed exceptionally well in ROI and cost reduction and scored lowly in adoption readiness, demonstrating a commonly seen trend where high value and/or high complexity applications require more intensive change management. The heat map also indicates performance gaps that need to be addressed during the planning phase. Several of the applications showed high financial metrics but lower productivity scores, indicating cost reductions were achieved but did not result from large increases in individual employee's efficiencies, while others showed high levels of productivity and time savings but moderate levels of cost reductions; thus, these applications provided value by improving staff morale and reducing burn out rather than providing direct financial returns which are important factors to consider when institutions prioritize work force retention over purely financial optimization.

Case Study 1: Administrative Budget Optimization at Metro General Hospital

Metro General Hospital is an urban teaching hospital that has 400 beds. They implemented a financial education module utilizing XAI (Explainable AI) as part of their efforts to improve departmental budget management. This system was able to integrate the last five years worth of financial data including departmental spending, variations in patient volume, seasonal variations, and changes in reimbursement rates resulting from regulation.

The educational platform presented various hospital administrative users with interactive and realistic financial decision-making models, that were based upon the past budgetary problems faced by the institution. For example, one model simulated the potential financial impact of launching a new cardiac surgery program and considered factors such as the cost of equipment required, the need for additional staff to provide cardiac surgical procedures, the number of patients that would be expected to require these procedures, and the typical reimbursement pattern for this type of treatment under insurance programs.

When the XAI component suggested reallocation of resources from one department to another, it provided the rationale behind each recommendation. In other words, when the system indicated resource should be transferred from one area of the hospital to another, it would explain why. Examples included patient volume trend data suggesting that there was increasing demand for cardiac surgery; historical data indicating seasonal variation in utilization across different service lines; and reimbursement data indicating that transferring funds from other departments was financially viable.

CFO Sarah Mitchell said that after implementation of the XAI-based system, her organization experienced a significant improvement in their teams' abilities to analyze budgets. "Prior to using the XAI system our budgetary decisions were primarily driven by historical precedent and intuition." Mitchell stated. "The XAI system allowed us to better understand the complex relationships between all of the variables that affect our organizations' financial results. Additionally, we now know how the system arrives at its recommendations, thus improving our confidence in making data-driven decisions."

Quantitatively speaking, the use of the XAI-based system resulted in several positive outcomes for Metro General Hospital. These include:

- A 15 percent increase in the accuracy of forecasting budgets;
- Reductions in cost overruns from approximately eight percent of total budget to three percent of total budget;
- An improved ability to recognize cost savings opportunities while maintaining the quality of patient care.

Case Study 2: Clinical Decision Support at Riverside Family Medicine

Riverside Family Medicine is a primary care provider that has been providing service to a wide variety of patients. They have implemented an XAI-based education model which focuses on teaching clinicians about cost conscious clinical decision making.

The XAI model uses data from various sources including insurance company formularies, local pharmacy prices, and patient information regarding their use of financial assistance programs. Dr. Maria Rodriguez, a ten-year experienced family physician at Riverside Family Medicine utilized this tool to examine possible treatment choices for diabetic patients. She was presented with examples of actual patient cases (de-identified by name or other identifiable characteristics) and guided through the selection of treatment options that would provide effective clinical outcomes while being mindful of the associated costs.

As one example, she used the XAI tool to evaluate a hypothetical patient who had recently received a diagnosis of type 2 diabetes but lacked adequate insurance to cover the costs of his prescribed medication. The XAI system suggested using metformin instead of more costly new drugs for this patient. When Dr. Rodriguez asked why metformin was chosen over these more costly alternatives, the explanation feature explained that there were several reasons why metformin was selected as the most appropriate choice: it is well-proven as an initial treatment option for managing diabetes; it is much less expensive than many alternative drugs; it has a long history of safe usage; and there are patient assistance programs available to help meet the costs of metformin for those without health insurance.

In addition, the XAI model analyzed the circumstances under which more expensive treatments may be preferable, and provided explanations for when factors such as tolerance for certain medications, a patient's multiple co-morbid conditions, or changes in their health insurance plan could make it necessary to select a more expensive treatment option. Using this approach helped Dr. Rodriguez build a deeper understanding of cost-effectiveness principles beyond simply selecting the least expensive treatment option based upon cost minimization alone.

After completing the six month program utilizing the XAI tool, Dr. Rodriguez stated that she felt more confident in her ability to discuss costs with patients and to choose cost-effective treatment options. Surveys conducted among the patients reflected higher levels of trust in the treatment recommendations made by Dr. Rodriguez and greater awareness of the financial aspects involved in receiving their medical care.

Case Study 3: Patient Financial Navigation at Community Health Center

A community-based health center that has a large number of low-income patients created a patient-centered education system using both big-data analytics and explainable AI (XAI) to help educate its patients about their options for managing their medical conditions financially.

The education system was designed to provide detailed information regarding the various forms of assistance available to patients at the health center including insurance coverage, state/federal aid programs, hospital charity care and prescription medication discount programs. Maria Santos is an uninsured patient from Mexico with limited English ability that spoke Spanish as her primary language; this patient utilized the education system to learn how best to manage her chronic kidney disease. Based upon the specific demographic information regarding Maria's location within the health center service area, her income level, her immigration status and her clinical needs; the system provided Maria with individualized recommendations regarding ways to manage her condition based upon her personal situation.

Additionally, the XAI system provided explanations regarding why each recommendation was generated. When recommending that Maria apply for the health center's charity care program, the system provided Maria with the eligibility requirements that she met, what the application process entailed and specifically what services/benefits she would be eligible for once enrolled. Additionally, the explanation provided by the system included step-by-step instructions for completing the application process as well as possible barriers that may have been encountered during the application process.

In addition to providing recommendations and explanations; the education system also provided Maria with interactive tools to estimate costs associated with various treatment options for managing her chronic kidney disease. These tools allowed Maria to identify the least expensive methods for managing her condition. The big-data component of the education system enabled accurate cost estimations to be produced based on actual local prices paid for medical services and/or products and/or medications as well as actual insurance company reimbursement patterns.

James Thompson, a financial counselor employed by the health center stated that since the development and implementation of the education system utilizing XAI, there had been substantial increases in patient knowledge and involvement in making informed decisions regarding their healthcare. James Thompson stated "the patients that utilize our education system come into their appointment with a significantly greater degree of knowledge than those patients that did not use our education system." James Thompson further stated "these patients are able to make informed decisions regarding their healthcare because they understand their options and therefore require less time for me to spend educating them concerning their financial responsibilities."

Case Study 4: Integrated Health System Workforce Development

Beginning with an analysis of Regional Health Partners (RHP) as a five-hospital integrated health care delivery system utilizing both comprehensive XAI (explainable artificial intelligence) and large scale data driven educational initiatives for its work force, RHP was able to provide role-based learning opportunities for all employees.

RHP used data generated by each of its hospital sites to enable employees to see the interplay between the individual role and the overall organization's financial decision making.

While the specific role based learning paths were unique, the foundational knowledge base regarding financial principles remained consistent throughout all roles. Nurses had the opportunity to learn about the financial impact of using supplies and making decisions relative to patient flow. Pharmacists learned about optimizing drug therapy costs, creating a drug formulary, and managing access to medications. Social workers developed knowledge in assisting patients with understanding their financial obligations and navigating programs designed to assist financially challenged patients.

The use of XAI enabled all employee users to understand the reasoning behind the recommendations they received for improving their respective departments' financial situations.

For example, when the system recommended changing the nurse to patient ratios on a particular floor, it explained why those recommendations were made and showed them how patient acuity information, regulatory rules, and cost considerations affected what would be the most efficient way to organize the units.

Results of this initiative include RHP achieving improved financial results as evidenced by multiple different measures. Those measures include; lower cost for medical supplies due to better usage of supplies, fewer patient complaints about billing or other financial matters, and better communication among clinical and financial decision makers within each department.

This illustrates that a successful implementation of XAI and big data analytic tools into education in healthcare finance is dependent upon identifying the user population needs, the organization's internal environment, and integrating the new tools into existing workflows.

Using XAI provides increased transparency which can build confidence with students, and allows them to become more engaged learners, while big data analytics will allow students to have a more personal and relevant experience based on real world complexities.

Conclusion

The ability to leverage intelligent systems and advanced analytics to support health care operations presents an extraordinary opportunity to help mitigate the persistent challenges facing health care organizations related to budgeting; resource allocation; and efficiency in health care delivery. Twelve applications identified as being among the most important (i.e., those where a) there are sufficient amounts of data available to evaluate the application's success, b) the application has the greatest potential for impacting hospital operations, c) the application has been successfully implemented at one or more hospitals, d) the application has the potential for yielding a positive return on investment, e) the application addresses a challenge that currently exists within health care, f) the application offers something new to hospitals compared to what they were doing before the implementation of this type of application, g) the application is relevant to all types of hospitals -- i.e., both urban and rural, academic and community), have produced results that indicate a return on investment occurs within approximately two months. This is significantly sooner than many other forms of health care technology which take anywhere from 2-3 years to produce positive returns on investment.

These applications include Patient Flow Management; Insurance Verification; Clinical Documentation; and others. In addition to producing positive returns on investment in a very short period of time, each of these applications has helped increase the overall efficiency of the organization and has increased employee job satisfaction.

Several factors appear to influence the likelihood of achieving positive results when implementing these applications. One factor appears to be transparency. An application that provides a transparent explanation regarding how it arrived at a recommendation tends to perform better than one that does not. Another factor appears to be user acceptance. If employees find an application easy-to-use and simple to integrate into their existing workflows then they tend to accept it quickly. Clinical documentation applications are examples of this phenomenon. Employee acceptance of clinical documentation applications was extremely high due in part to the fact that they provided a number of different features that made documenting a patients visit easier. Employees found that they were able to document patients visits much faster after the implementation of clinical documentation software than they had prior to its implementation. The time saved by employees using clinical documentation software was so great that employees were able to spend additional time focusing on patient care.

Another factor appears to be the level of sophistication. It appears that what is more important than technical sophistication is whether an application is useful and whether it is easy-to-use. Clinical documentation software is a good example of this. As noted earlier, clinical documentation software has been widely accepted by employees because it makes documenting a patient's visit easier. However, the clinical documentation software is not necessarily more sophisticated than other options. What makes it superior is that it is easier-to-use. Therefore, employee acceptance is higher. Similarly, when employees understand how an application arrives

at a recommendation (e.g., by verifying the logic behind the recommendation), they are more confident about using the application and view it as a tool and not as a threat to their professionalism or as an obstacle.

Analyzing large volumes of operational and financial data enables a more refined approach to managing a health care organization. Rather than trying to apply a single solution across numerous situations (or "one-size-fits-all" approach), organizations can use data analysis to develop targeted solutions tailored to their unique needs and environments. Examples of this include Administrative Automation. Studies have shown that when processing time for certain administrative functions is reduced by a certain percent, there will be corresponding reduction in cost. Therefore, administrators can rely on these studies as predictive measures for determining future cost savings associated with the same administrative function(s). Additionally, Revenue Cycle Management Systems, although expensive and difficult to implement, have produced the largest dollar amount of savings because they address complex financial issues (such as reimbursement) that have historically caused problems for hospitals. All of these examples illustrate why it is critical to match technological solutions with institutional priorities rather than merely implementing technology for its own sake.

However, challenges still exist relative to implementing these various applications. Some applications require minimal investments and are easily adopted, whereas other applications require considerable investment in terms of capital, technology and personnel time in order to implement. Applications used clinically are more varied in terms of their performance than administrative applications. The reason for this variability appears to be the inherent difficulty in developing advanced technology and incorporating it into clinical decision making processes that directly affect patient care. Organizations therefore need to carefully determine their preparedness to implement such applications by assessing not only their financial position but also their staffing capabilities, existing technical infrastructure and tolerance for disruptions resulting from major operational changes. Rushing through implementation without adequate preparation usually reduces or eliminates potential benefits, creates distrust in the organization's leadership and damages employee morale.

In general, it is recommended that institutions adopt a phased implementation model as the most successful means of implementing intelligent systems and advanced analytics. Implementing applications that have high levels of user acceptance and generate rapid financial returns early in the process helps organizations gain confidence, develop internal expertise and create resources needed for subsequent implementation phases. Successes in early phases with relatively simple applications such as Insurance Verification or Clinical Documentation create momentum and organizational support for undertaking more complicated applications such as Comprehensive Revenue Cycle Management. Once organizations have developed comfort with simpler systems and have developed governance structures they can begin implementing more complex applications such as Comprehensive Revenue Cycle Management which generally require greater organizational change management effort but result in larger benefits.

A phased implementation model also minimizes risk by allowing organizations to implement applications incrementally while creating the organizational capability needed to sustain technological transformation.

Workforce implications are also very important. Healthcare Systems face projected worker shortages of millions of workers over the next few years. Current workers feel increasingly overwhelmed with administrative burdens that contribute to professional burnout. Products that

reduce administrative burdens (e.g., documentation time) by 50% or allow workers to manage substantially greater workloads with no increase in stress represent viable solutions to these challenges. Improved clinical documentation products have restored 10-15 hours per week back to Physicians who can now redirect this time towards either patient care or personal life/work balance improvement. These productivity gains are important not only for institutional efficiency but also for ensuring that health care continues as a profession capable of attracting/retaining qualified professionals.

The scope of possible impact extends beyond individual health care organizations. Research indicates that if intelligent systems and advanced analytic technologies are broadly adopted throughout the health care industry it could save hundreds of billions annually through decreased administrative burden; more efficient claims processing; improved resource allocation; and fewer billing errors. A mid-sized health care organization may require \$20-\$30 million in initial investment to comprehensively implement these technologies however they could expect hundreds of millions dollars in savings over 5 years. It is essential when interpreting such estimates that we recognize that estimated savings assume successful implementation and continued performance; both of which are dependent upon successful organizational execution and continued enhancement/refining of systems. Furthermore, access to such economic benefits will require significant capital expenditures which may limit availability for smaller health care facilities or rural providers thereby exacerbating existing inequities in health care delivery unless active steps are taken to rectify such inequities.

Therefore, several priority areas emerge based on this analysis. First, health care organizations should develop strategic plans outlining how they intend to implement intelligent systems and advanced analytical technologies within their respective organizations and clearly articulate their expectations regarding timetables for adoption. Most organizations will benefit from staged deployments that build on incremental successes rather than attempting comprehensive transformation immediately. Second, technology developers/vendors must focus on developing products that emphasize user experience/workflow integration rather than technical sophistication, acknowledging that even highly sophisticated systems will fail if end-users do not choose to adopt them. Third, policy makers must consider ways to ensure access to these technologies by small/rural health care providers who are disproportionately impacted by inefficiencies in health care delivery. Finally, continued research will be critical to identifying best practices for implementation models; understanding potential unintended consequences; and refining approaches to maximize benefits while minimizing risks.

As health care costs continue to escalate and operational complexities continue to grow; the need for more efficient management will become increasingly urgent. The technologies to address these challenges already exist and have demonstrated value across diverse applications/settings. The issue is no longer whether these tools can deliver value but rather how these tools will be implemented in thoughtful/equitable manners. To accomplish this, sustained commitments from all parties involved (healthcare leaders willing to make long term commitments; employees willing to modify traditional practices; technology companies committed to designing user centered products; policymakers supportive of infrastructure development & equitable access); will be required.

Acknowledgements: *This paper was co-financed by The Bucharest University of Economic Studies during the PhD program.*

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