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Modernizing Legacy Software in U.S. Enterprises Through Cost-Effective AI-Driven Optimization

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Abstract

The modernization of legacy software is a growing priority for U.S. enterprises that want to remain political or business competitive in a data-driven economy. Although legacy systems often serve a central role in an organization or department, they come with various burdens including high maintenance costs, low elasticity scalability, and a lack of interface capacity with modern technologies. Therefore, like many aspects of innovation and digital technology, Artificial Intelligence (AI) has the potential to transform legacy systems by allowing automated code refactoring, in system optimization, and process decision management. The authors present a comprehensive review of AI-enabled approaches to successfully and cost-effectively modernize legacy systems for enterprise applications. They highlight the need to provide organizations and enterprises with the ability to be adaptive or flexible in a sustained and cost-effective manner for a wide scope of legacy system modernization.

Based on new literature in legacy systems using AI, the authors provide examples of applications in enterprise resource planning, smart manufacturing systems, cloud integration and migration, and multi-cloud optimization and cost savings activities. Also presented are frameworks and best practices for successful implementation for each of these new areas, and the opportunistic challenges of analysis complexity of integrated systems, integration to newer technological spaces, and systems knowledge or skills gaps. The data shows that while AI extends current functional capacity of legacy systems, it also calibrates legacy systems within current governance expectations, strategic outcomes for digital transformation, flexible scaling and strategies for secure cloud capabilities, and is the safest and most cost-efficient approach to modernizing legacy systems to enhance or to reduce enterprise risk.

Keywords: Legacy System Modernization; Artificial Intelligence Integration; Cost-Effective Enterprise Transformation; AI-Driven Software Optimization

1. Introduction

With the speed of technological change now careening around corners with wheels, American businesses face the challenge of operating legacy software systems whilst simultaneously moving towards more agile, data-based software systems. Much of the operational functionality in sectors is supported by legacy software system, which is often described as legacy or old architecture, outdated programming languages and insufficient or no integration with current systems. The relevant industries that include finance, insurance and even the government have loads of old-fashioned software that is still in operation. In addition, the operational expenses of maintaining legacy systems are enormous, and subject companies to potentially damaging cyber threats, and thwart potential innovation. Code refactoring process, application integration, and application tuning/performance may take a long and complicated process of modernization. In the wake of AI, optimization, which can now be achieved with the help of AI, is assisting business and operational leaders in this process by making it faster and easier.

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Generative AI (Artificial Intelligence) as a form of generative model, machine-learning approach, and intelligent automation, is being employed more and more as a strategic facilitator of modifying outdated infrastructures to scalable, efficient, and resilient digital ecosystems. The trend to modernize legacy systems with the help of AI is not only a technological but also an economic necessity in the U.S. business. Modernization benefits of the artificial intelligence of legacy systems are shaping into an economical approach that borders affordable the long-term sustainability of digital transformation strategies in industries such as government, healthcare, manufacturing and defense. The paper is a review of how AI-based solutions are implemented to modernize legacy software within the U.S. in terms of cost-efficiency, technical viability and business maturity.

2. The Case for AI-Driven Legacy System Modernization

AI's contribution to legacy system modernization is primarily based on its substantial code-reading capabilities, identifying inefficiencies, and automating the reconfiguration of outdated software architectures to modern frameworks. One major use case is automated code translation, where generative AI models are developed and trained to translate procedural or monolithic code bases into object-oriented or service-based frameworks. AI and automation minimize the manual work effort, and the associated cost, of modernizing a code base and preserves business logic and functionality [1].

Generative AI can also be used to refactor code. It can study the legacy code for inefficient segments, dead code segments, and security vulnerabilities, and recommend or make changes to the code accordingly without supervision. By employing AI to refactor code, enterprises continue to operation unencumbered during the modernization process, avoiding excessive, moderate or no downtime and disruption. AI refactoring allows compliance and actionability in relation to modern security standards and software development best practices [1].

Modernizing legacy systems is related not only with allowing technology to advance but also in order to reorganize the software underpinning such systems to adhere to the strategic aims of the business and to even take them forward. The emphasis on strategy instead of technology is critical on the occasions when legacy systems are made in continues in safety-critical contexts within highly regulated environments such as defence. There are processes being looked at, in conjunction with the application of AI-enabled decision modelling, by the U.S. Department of Defence demonstrate an ability to compress the timelines associated with modernisation at reduced costs. Formidable work is being undertaken in the defence sector with regards to AI-based simulations, as well as predictive analytics, that provide decision makers with the capacity to understand the edge cases and compromises that take place between modernising a legacy system and completely replacing it [2].

AI is also being applied in defence contexts to manage the lifecycle of legacy systems, considering models for when components are likely to fail, when to allocate resources, as well as budgets on projects. The extent to which they can model and simulate across these various frameworks, is still critical to ensuring that they remain on target and on budget with modernisation as well as being mission-critical operationally ready [2].

3. AI Integration in Enterprise Resource Planning Systems

One of the more proposed proposed and highly visible applications of AI in the public sector that are suggested is transforming the older Enterprise Resource Planning (ERP) systems such as PeopleSoft Human Capital Management (HCM) to more current and modern. PeopleSoft HCM and others have been complex systems that are not flexible and have a notorious reputation of being difficult to scale. The capabilities of AI that are being leveraged by public agencies include natural language understanding, robotic process automation, and predictive analytics, which provide some benefits in terms of how far the older ERP systems are to a new HR operationalization of organizations. [3].

AI allows making decisions and automation of business-processes, including onboarding of workers, payroll processing, and managing compliance processes. PeopleSoft HCM cannot be fundamentally or radically transformed, however; the smart capabilities can be overlaid on the existing functionality that enables the decrease in manual entries, faster document processing, and the provision of dashboards that would give the insight into the workforce metrics nearly in real-time. The technology has been updated, and although enhancements have been done towards the user experience, and operational efficiencies, the technology seems to be altered [3].

The upgrades are being done in phases, to allow government departments to maintain certain existing investment in infrastructure, and at the same time introduce AI capabilities in the modernized and modular manner. Hybrid models are cost effective and minimize disruption associated with system change and system replacements [3].

4. Strategic Cost Management and AI Optimization

Cost modernization of software systems at scale in large organizations comes with substantial costs—not only in terms of expenditures but also in terms of time, lost productivity, staff training and development, and lost time for downtime of systems. Even though it is difficult to quantify the costs, AI can facilitate the modernization costs and associated efficiency through effectively managing time and resources. Programs can employ project management tools enabled by AI such as those provided by Microsoft and explain it in the company KPIs (key performance indicators), resource allocation, and benefits of any associated value created in modernization of system and interdependencies of the systems in an organization [4].

Cost efficiencies gained in utilizing cloud-native architectures as they become enabled to interact with AI services. Transitioning from an on-premises legacy system to a cloud-based continued service where AI is integrated, enables on-demand pricing for compute power elastic capability for storage space, and allows the vendor to think about and implement vigorous cybersecurity. Subsequently, organizations are reducing costs and the need to replace costly hardware every few years and diminish overhead and maintenance costs associated with the data centers. By modernizing a system it allows small and medium-sized enterprises to truly modernize and provide return on investment on hardware upgrades to commercialization [4].

AI also contributes to cost control via predictive maintenance of software systems. AI systems can assist in the identification of impending failures or system lags to avoid unplanned downtime, thus potentially avoiding costs. Monitoring software health in this preventative way is especially beneficial in mission critical environments such as healthcare and defense where system failure carries significant risk [4].

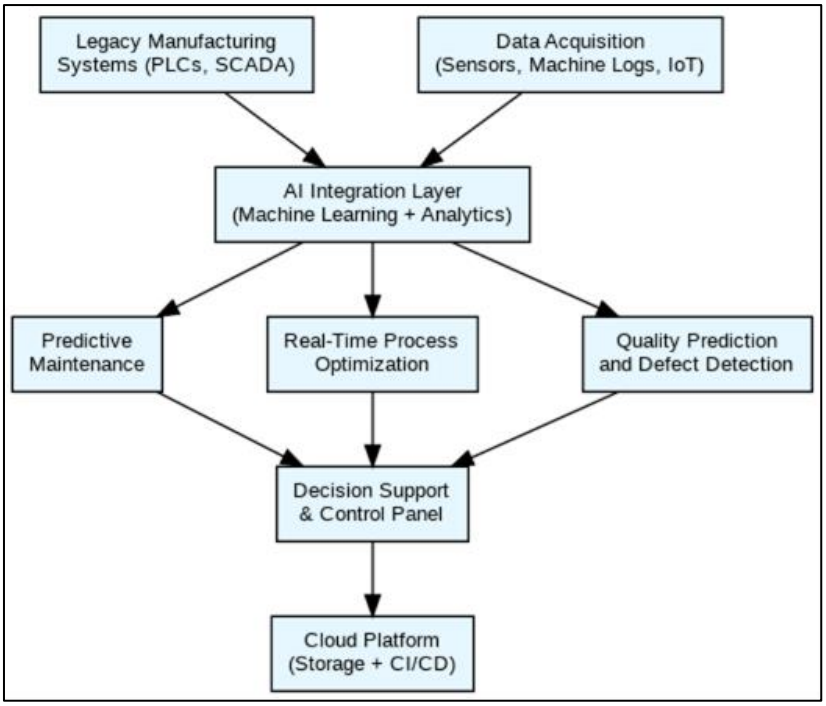
5. AI in Smart Manufacturing and Industry 4.0

The application of artificial intelligence (AI) in the context of modernization of legacy systems within the scope of Industry 4.0 is most notably prevalent. In smart manufacturing, organizations currently have legacy systems that have historically run programmable logic controllers (PLCs), supervisory control and data acquisition (SCADA) systems, or level of machine interface. While they work, those systems lack the interoperability, adaptability, and data analytics that AI provides via intelligent process control, real-time analytics, and automation [5].

In the case of manufacturing enterprises in the United States, the retrofitting of legacy systems with AI allows machines and software to communicate through the Internet of Things (IoT) framework, hybrid cloud, and edge processing. The interoperability in AI-enabled legacy manufacturing software permits manufacturers to not only measure, monitor, or predict their production in real time, but to perform adaptive quality control and process optimization. Therefore, manufacturers achieve more throughput, less waste, and a more resilient supply chain [5].

The incorporation of AI into legacy manufacturing software also facilitates energy optimization, a critical component to sustainability in production systems. Machine learning algorithms will examine energy usage and the operational profile of a facility and be optimized to use as little energy as possible, producing cost savings, and complying with environmental regulations [5].

The following diagram depicts the architecture of in most manufacturing environments of the AI-enabled modernization:



Source: Adapted from [5]

Figure 1 AI-Enabled Legacy Modernization Architecture in Manufacturing

6. Best Practices and Frameworks for Legacy Modernization

The strategic application of best practices and frameworks is critical to successful AI driven modernization. The way of modernization is gradually being adopted by enterprises, in which enterprises will use the help of AI tools to study the existent systems before modernization, determine priorities to be modernized, and develop resiliency roadmaps. This assists in reduced risk and at the same time making the project connected with business results [6].

Other important best practices are to use AI to reverse engineer legacy code to assist in isolating reusable assets and core workflows, to guide modular modernization strategies whereby enterprises would be modernizing certain bits of legacy systems, rather than replacing entire legacy systems. Besides this, the enterprises are seeking to adopt containerization and architectures of microservices that can allow enterprises to gradually transform legacy systems into modern systems through AI based orchestration tools so that the modernized systems and/or capabilities may co-exist with the other system invested sustainable capabilities [6].

AI is also finding its application in change management, namely, to minimize opposition by organizational workers who use legacy systems on a regular basis. It may involve custom training, virtual assistants and intelligent documentation, and it can help to make the process of transitioning much smoother, as well as shorten the time that the end-users will require to ramp up [6]. A summary of strategic objectives and their AI-driven solutions is provided below:

Table 1 Strategic Objectives and AI-Driven Modernization Solutions

Strategic Objective	AI-Driven Solution
Cost Reduction	Predictive analytics, cloud migration
Improved Performance	Automated code optimization and testing
Enhanced Security	AI-based vulnerability scanning and anomaly detection
Greater Scalability	AI-enabled microservices and container orchestration
Business Continuity	Intelligent backup, recovery, and fault tolerance systems

Source: Synthesized from [1] [4] [6]

7. AI in Software-Defined Manufacturing and Process Optimization

AI is driving change beyond traditional manufacturing processes to software-defined production systems, which rely on flexible, programmable systems for manufacturing and entail controlling manufacturing processes with software logic instead of relatively permanent hardware. For companies using legacy systems, this is a substantial shift in operational flexibility and innovation. In this transformation, AI performs the role of an intermediary by dynamically converting legacy processes to programmable service that can be changed, size-scaled, or replaced and installed with minimal disruption to the existing physical processes [7].

Software-defined processes that can utilize AI include automated and intelligent scheduling, workload management, and automated quality control. Algorithms based on machine learning capabilities analyze production data as it flows through the manufacturing system and either adjusts production system parameters dynamically or triggers action to ensure outputs are produced using the optimal process and materials to meet quality specifications. This dynamic adaptability can overcome many of the static controls imposed by the legacy manufacturing system, which were statically controlled by random acting or scheduled events, parameters [7].

In addition, AI is also more effective in integrating legacy systems with new technologies, such as additive manufacturing, robotics, and industrial IoT. The implication of this interoperability is that modernization is not merely the process of upgrading your software but of the greater effect of modernization, which is the development of smart factories, and the integration of cyber-physical systems [7].

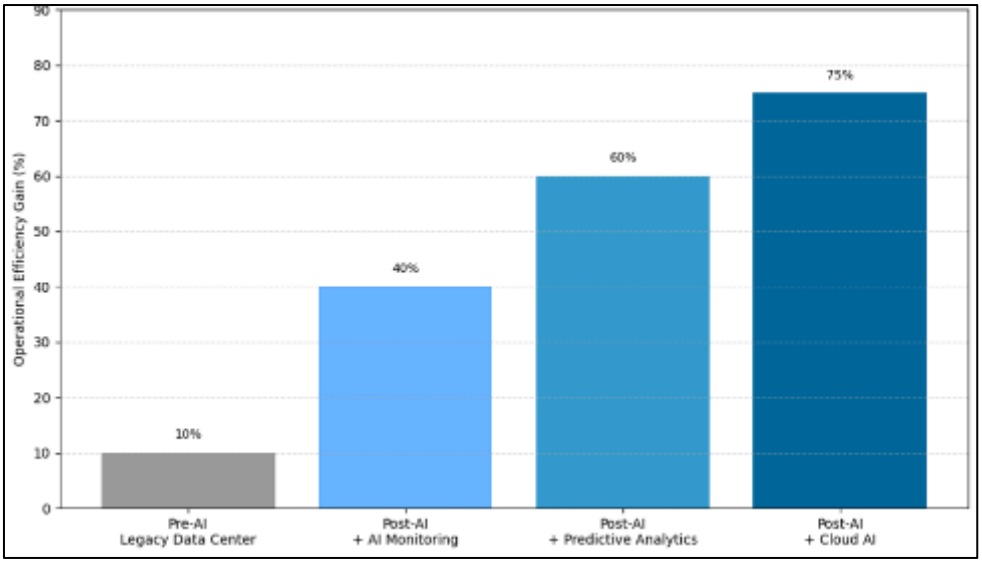
8. AI-Enabled Intelligent Data Centers for Legacy Support

The other aspect that AI assists the enterprises with in modernizing their old systems is in the infrastructure that supports enterprise applications. Organisations frequently require to refresh their direct operations in relation to on-premise infrastructures, and data centres that have legacy systems where operational practices, power consumption, server workload utilisation and maintenance prices are usually not well managed. The AI is changing the conventional data centers into new intelligent centers, which allow organizations to utilize energy in a more efficient manner, achieve higher productivity of the workloads, and enhance the reliability of operations [8].

The AI monitoring capabilities can help organizations in real-time monitor heat-maps, energy consumption, and workloads provided via their legacy enterprise systems platforms; to offer the prospect of proactive cooling, optimal server usage, and upstream detection of imminent system inefficiencies. Such qualities do not only cut down the operating cost, but offer some form of assurance that the system can not only exist, but it can be modernized as well [8].

In more recent times, workload migration capability analysis has also been provided by AI to organizations to migrate to upgraded (and sometimes significantly cheaper) cloud or hardware based environments to run legacy applications. As an example, AI can be applied not only to determine the trend in use and performance metrics, but to give guidance on what does enterprise middleware platforms can be left on-premise, rehosted or re-platformed. This kind of smart orchestration is important to organizations that do not desire to take the risk of going through a modernization effort at the cost of paying very high re-hosting or re-platforming costs as a result of service interruption [8].

The effect of AI on the efficiency of data centers operations is evidently reflected in the graph below:



Source: Adapted from [8]

Figure 2 Operational Efficiency Gains from AI in Legacy System Support

9. Scalability Through Cloud-Based AI Solutions

One of the requirements of modernization of legacy systems is scalability, since at some point, companies will expand or become diversified, a legacy system was not built to support the elastic nature of modern digital enterprises. Cloud based AI solutions offer a scalable cost effective modernization platform, by enabling the abstracted away compute and storage resources into dynamically offered services.

In this context, AI will provide an assist to the workload balancing, provisioning and performance administered activities. Companies will be able to deploy AI learning algorithms to assess systems needs and allocate cloud resources in real-time to meet those identified needs and provide optimal performance. These systems also learn based on our user patterns and even predict future resource needs while 'offering' the organization a scalable solution without altering the cost sphere [9].

Cloud AI enables CI/CD Pipelines. Reducing the manual work of dealing with the current legacy code bases. By adding AI to the DevOps operations, the developers will be able to and will automate the testing, debugging, compliance checking to modernize code in a significantly accelerated schedule. The improvements above reduce time-to-market max speed, eliminate the software capability distance, and agility business will want [9].

The introduction of AI-driven cloud infrastructures brings up enterprise-wide shared dashboards to indicate the possibility of modernising legacy development, either at department or business unit levels. These dashboards offer visibility on modernization enterprise-wide measures across the departments that encompass cost, performance and risk level that enlighten superior enterprise-level strategic planning [9].

10. Strategic Business Optimization and AI-Driven Legacy Integration

The application of AI in the modernization of the old systems can capitalize on the overall enterprise strategies, namely on the supply chain optimization, customer experiences and internal functions. The advantages of applying AI are magnified when AI is incorporated into the operations systems of the business, new access to higher decision-making systems, which will dramatically boost responsiveness and agility but remain capable of operating in dynamic and changing business environments [10].

The actual implementation of AI as a supply chain optimization applies to the functionality of legacy systems. Imagine artificial intelligence (AI) predictive models strategically mounted on top of the current enterprise resource planning (ERP) systems to achieve enhanced prescriptive skills on the way of demand forecasting, determining bottlenecks and enhancing inventory optimization. Installation of predictive models does not override existing enterprise resource

planning (EPR) but rather, develops AI microservices that can conveniently fit in the existing ERP (through APIs or middleware) [10].

Internally, AI enables strategic workforce planning and resource allocation by analyzing historic usage data from legacy systems and aligning this data with business objectives. Therefore, companies are empowered to redeploy human capital, redevelop employees, or reorganize teams based on data insights from an AI-enhanced legacy platform [10].

Additionally, AI offers micro data segmentation and behavioral analysis to legacy customer-facing systems, as in Customer Relationship Management (CRM) systems. By adding AI modules to legacy customer databases, companies are able to offer greater service personalization, recommend products or services, and even predict customer churn while also maintaining improvements to legacy systems [10].

11. Challenges and Mitigation Strategies

Even with significant benefits in AI-driven modernization, there were some challenges necessary to overcome for success. The primary challenge was the technical complexity of attaching AI to legacy or proprietary systems. Legacy systems generally do not have standardized interfaces for modern API tools to offer an off-the-shelf plug-n-play solution. Instead, the integration of AI toolkits into legacy systems typically requires some customization.

To solve this issue, many enterprises are leveraging middleware frameworks and API gateways as translational layers between legacy systems and modern AI modules. These tools enable bi-directional communication and data transfer between systems that differ architecturally. The middleware allows for the legacy systems' potential and AI to be exploited, solving the problem of architecture incompatibility. In addition, code analysis tools are powered by machine learning to reverse engineer the legacy software and produce documentation, to aid the integration [6].

Cybersecurity is yet another major challenge. AI tools integrating with legacy systems may introduce unknown attack vectors if the legacy systems are not secured. AI systems, and any systems augmented with AI capabilities, will need to be secured using zero-trust models, continuous authentication systems, and anomaly detection algorithms to provide adequate protection from threats.

Another growing challenge is the skills gap in managing AI-enabled modernization. Many legacy system administrators do not have the skill set to implement and manage the AI-augmented systems. Enterprises have begun to deploy cross-function training in which legacy IT teams learn about AI and cloud computing to develop capabilities [6].

12. Conclusion

AI-enabled modernization of legacy software systems is a transformational opportunity for U.S. enterprises pushing to build cost-effective, scalable, and resilient digital foundations. AI offers automated code translation and intelligent ERP advanced capabilities, cloud-scale processing, and organizational alignment that enables businesses to preserve the value of their existing systems as they prepare for more complex use of single platform technologies in the future.

By enabling enterprises to utilize predictive, automated, and optimized AI capabilities, organizations reduce the cost of modernization, operational risk, and provide greater business agility with a phased integrated transformation. While challenges such as integration complexity and security threats remain, these challenges can be accomplished by framing tools, training, and hybrid architecture.

The aim of using AI is not necessarily to replace previous systems, rather to replace them with intelligence—to change old technologies into intelligent platforms that facilitate enterprise-wide growth and innovation for the future.

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