



WHITE PAPER

AS/400 Modernization



MIGRATION TO CLOUD

Abstract

Large enterprises often run mission-critical workloads on AS400 applications that are older, difficult to maintain and expensive to operate. Today, many enterprises want to migrate their workloads – including their AS400 portfolios – to cloud to gain higher scalability, agility and cost benefits. This white paper examines the challenges of modernizing AS400 workloads along with the common AS400 migration approaches and useful architecture patterns that ensure maximum benefit from cloud migration. This paper will be useful to IT professionals and business decision-makers in organizations looking to either migrate or modernize their existing AS400 or other legacy workloads to cloud.

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2. Introduction

The AS400 (also known as the 'IBM iSeries' and 'IBM i') is a previous generation mid-range computer system that was designed for small businesses and departments in large enterprises. AS400 is well-known as a world-class application server with proven robustness, scalability, reliability, security, and low cost of ownership. As new technologies and devices emerge and transform the way we conduct business, there is increasing demand to modernize AS400 applications to harness greater value.

Typically, AS400 systems store large volumes of valuable information and core business logic. As data becomes a key driver of success in today's economy, companies are looking to leverage and reap the benefits of this stored information. However, there are limitations within existing AS400 applications. Monolithic code, 5250-based 'green screens', tightly coupled business logic, etc., along with balancing cost, risk and value pose serious challenges in modernizing these systems.

AS400 applications are critical to business as they drive revenue and support customer needs. But, as the architecture

for these applications becomes obsolete, it can impede business growth. From a modernization perspective, cloud technologies can significantly improve system agility, scale and speed. However, most enterprises still depend on AS400 applications and have legitimate concerns when it comes to adopting cloud.

Typically, AS400 applications involve sunk costs as IBM does not charge customers based on the number of transactions processed. This means that AS400 is not an expensive server to maintain. Thus, any modernization initiative must deliver benefits beyond merely reducing cost. It is important to note that when AS400 servers expire in future, IBM will no longer support their OS. Thus, these applications will require a server/OS upgrade to continue functioning. As server/OS upgrade costs can be high, migrating your AS400 portfolio to cloud is an option worth considering.

Given the large AS400 footprint on the IT landscape and the variety of technologies, databases and supporting software involved, a one-size-fits-all solution for AS400 modernization is unlikely to succeed. Enterprises looking to modernize their AS400 applications need

a customized approach that reduces TCO, unlocks insights from hidden data and increases system agility while delivering consistent business value.

2.1. Infosys Cost Assessment Framework- Upgrade or migrate?

Upgrading AS400 applications goes beyond mere hardware/software upgrades and involves upgrading third-party vendor licenses, peripherals, etc. All of this can increase the total upgrade cost along with other factors such as:

- Older out-of-support operating systems like V5R3, V5R4, V6R1, etc., need to be upgraded to maintain support for applications running on this OS
- The AS400 OS lifecycle is 3-4 years and will require frequent updates in future
- Frequent updates will lead to further third-party vendor support/license costs
- Upgrading toolsets/utilities/peripherals are an added cost

Depending on your organization's IT environment, the total cost to upgrade AS400 may be higher than that of migration. Further, upgrades will not



provide the scalability, agility and future-ready architecture that is easily available on cloud.

To help companies find the best-fit solution, Infosys provides a cost assessment framework along with several

tools that yield a cost-benefit comparison between upgradation and migration. This allows customers to choose the most appropriate option that suits their business needs.

Let us see how, Infosys enabled a retail

client with large AS400 application inventory to calculate their AS400 upgrade and running cost (as shown in Figure 1) and compare this with the total cost of migration. The client chose migration for their AS400 applications and realized significant benefits over the next 10 years.

Item	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	Total
Option I - Continue in AS400											
Continue in AS400	\$2,070,000	\$220,000	\$220,000	\$220,000	\$1,370,000	\$220,000	\$220,000	\$220,000	\$1,070,000	\$220,000	\$6,050,000
Option II -AS400 Migration Cost											
Services Cost -Labor (One Time)	\$2,500,000	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$2,500,000
Software Cost	\$125,000	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$125,000
Other Remediation Cost	\$275,000	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$275,000
Infrastructure Service Cost	\$250,000	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$250,000
Product Support and Annual	\$150,000	\$150,000	\$150,000	\$150,000	\$150,000	\$150,000	\$150,000	\$150,000	\$150,000	\$150,000	\$1,500,000
Total Migration Cost	\$3,300,000	\$150,000	\$150,000	\$150,000	\$150,000	\$150,000	\$150,000	\$150,000	\$150,000	\$150,000	\$4,650,000
Cummulative Migration cost	\$3,300,000	\$3,450,000	\$3,600,000	\$3,750,000	\$3,900,000	\$4,050,000	\$4,200,000	\$4,350,000	\$4,500,000	\$4,650,000	\$4,650,000
10 Year Total Projected Savings	(\$1,155,000)	\$145,000	\$145,000	\$145,000	\$1,295,000	\$145,000	\$145,000	\$145,000	\$995,000	\$145,000	\$2,150,000
Cummulative Savings	(\$1,155,000)	(\$1,010,000)	(\$865,000)	(\$720,000)	\$575,000	\$720,000	\$865,000	\$1,010,000	\$2,005,000	\$2,150,000	\$2,150,000

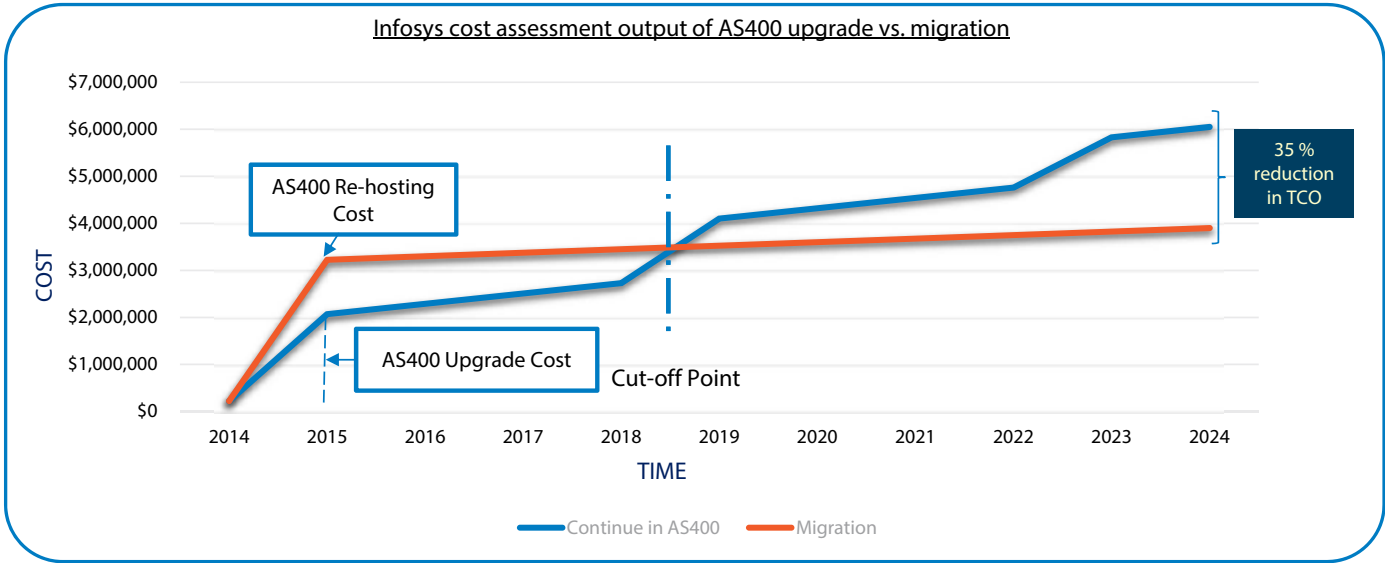


Fig 1: The comparison between the client’s overall investments for AS400 upgrade versus migration

It is important to note that since every business is different, the best-fit solution arising from the Infosys Cost Assessment Framework may not necessarily be migration from AS400. In some cases, organizations have chosen to upgrade AS400 by modernizing their applications to overcome existing challenges instead of migrating to cloud.



3. AS400 migration to cloud

3.1. Migration challenges

AS400 migrations are complex. They require different approaches depending on the requirements, workloads and risk profiles. There are several challenges that can delay an AS400 migration project. Customers often have limited views of their AS400 applications, lack a clear business plan to address their needs, understate the risks involved, and lack proper funding for long-term modernization projects. Further, there are many types of migration patterns

to consider – from re-hosting to enabling full-scale cloud native re-engineering. Whatever the approach, the organization must have a dedicated plan, a migration methodology and future-proof cloud architecture.

Infosys recognizes these challenges and works with customers to overcome them. The Infosys ART Modernization Framework determines an appropriate migration approach that meets individual customer requirements. Infosys has also developed an innovative approach to AS400 migration

that combines tools, experience and competencies in migrating workloads to any cloud service provider (Amazon AWS, Microsoft Azure, etc.), thereby addressing typical concerns such as cost, security and agility during an AS400 migration program. Combining an AS400 migration with data center transformation offers faster return on investment (ROI) through economies of scale. Customers can benefit from scalable architecture patterns, advanced real-time analytics and faster launch of new features to market within weeks or days.

Migration challenges	Infosys proposition
Limited knowledge of AS400 applications Most organizations lack detailed understanding and documentation of the AS400 application and batch jobs. Further, the existing knowledge is often limited to few subject matter experts (SMEs) who are part of a shrinking talent pool.	Infosys uses a tool-based knowledge engineering approach for knowledge discovery and to minimize dependencies on SMEs.
Lack of clear business plan The AS400 footprint in large customers varies from 10 to 100 million lines of code (MLOC). For such large portfolios, a robust framework is required to determine what to contain/maintain, what to renew and what to migrate.	Infosys has developed a set of business and technology patterns that create a roadmap for delivering continuous business value.
Migration risk Depending upon the migration approach, old and new systems may have to be kept in sync using hybrid cloud architecture to ensure that the end-to-end processes are not broken. Additionally, large amounts of data will have to be cleansed, transformed and migrated to the cloud in a secure manner.	The Infosys AS400 data migration tools and testing framework minimizes migration risk during this phase.
Delayed migration The longer it takes to carry out the migration and sync the old and new systems, the greater the complexity and risk.	Infosys recommends a people, process and technology-based approach where fewer SMEs leverage the migration tools and thereby accelerate the journey to the target state.
Inadequate funding for the migration journey Most companies face challenges when building a viable business case for AS400 migration.	Infosys helps customers develop business cases by providing outcome-based pricing and future-proof architecture.
Low expertise While customers usually have a deep understanding of the AS400 workloads they run, they may not be experienced in migration of those workloads.	Infosys has worked with several customers to transform their AS400 portfolios and enable migration to x86-64 platforms. We leverage best-in-class tools and approaches during these migration projects along with proven experience, best practices, reference architectures, integration patterns, and risk mitigation to successfully achieve migration of AS400 applications.
Fear of change AS400 migration and transformation exercises require strong change management as many internal teams may be involved and not all of the migration work is technical in nature.	Infosys' experience in change management and AS400 migration ensures seamless adoption of the new solution while allowing customer teams to focus on their core activities. To promote customer comfort during the transformation, Infosys performs a short assessment of the AS400 during the planning stage. This allow both the customer and Infosys to understand the change management requirements.

3.2. Migration approaches

To ensure that cloud migration generates sustainable business value, it is recommended to careful evaluation using the Desirability, Feasibility and Viability (DFV) framework and leverage one or more of the following migration solution approaches:

- Re-host low touch AS400 portfolio as-is on the cloud to reduce cost and increase scale
- Migrate batch jobs to the cloud to reduce complex code, make code near real-time or event-driven and leverage open source tools

- Re-engineer AS400 applications and processes as cloud native workloads for future-proof architecture

Let us explore each of these approaches in detail.

3.2.1. Re-hosting

Re-hosting AS400 is seamless from an end-user perspective. and it doesn't require change to existing interfaces or functionality. The application re-hosting solution runs existing AS400 applications on an x86-64-based cloud instance using a AS400 emulator like Infinite I, Baby I, etc. While standard AS400 technologies such as RPG IV, COBOL, CL, and DB400 do not require any change, some non-

supported technologies such as older versions of RPG and System 32 may have to be remediated. It is important to identify these technologies during the knowledge curation phase in order to create a remediation plan before migration. Functionalities that use third-party tools such as schedulers, printing, reporting, backup, analysis tools, Message Queues, and tape management are also migrated to a Windows or Linux equivalent.

Infosys works with various re-hosting and enterprise software partners to deploy and manage their software on the cloud. For a full listing of the software partners, please visit the Infosys Mainframe Modernization website.

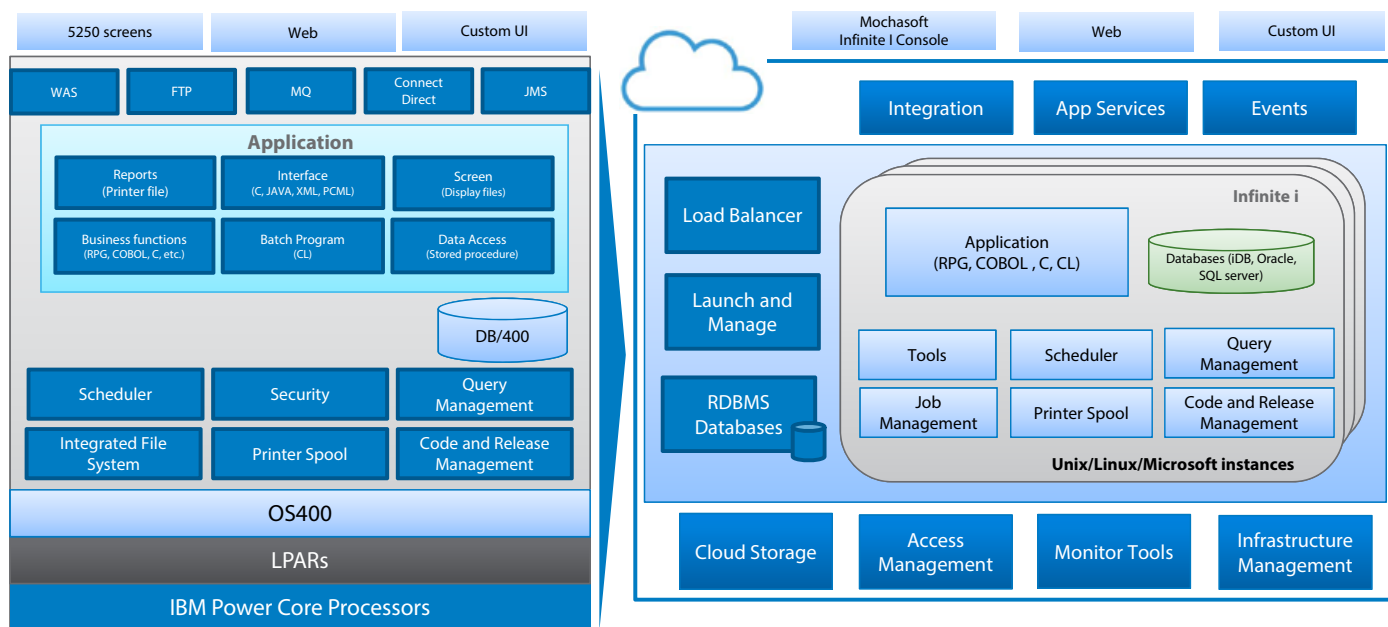


Fig 2: Functional architecture for the migration of an AS400 workload to the cloud

As shown in figure 5, Linux/Unix or Windows instances on cloud host the emulator where the legacy AS400 source code is compiled and deployed. Load balancers route traffic from the users to the re-hosted application. Data is migrated to a relational format and hosted on cloud SQL-based relational database using a modern database engine. Back-ups of the entire environment are stored in long-term, redundant and durable cloud

storage. From a security perspective, an LDAP directory is deployed to handle authentication and authorization requirements. Cloud access management provides fine-grained policy controls across the entire cloud ecosystem. Finally, cloud monitoring tools provide operational control of the entire environment through detailed monitoring and alerts.

3.2.2. Re-engineering batch job migration

Batch jobs forms a significant portion of the AS400 application portfolio. While batch processes are business-critical, many of these jobs have low business value. Running these on the AS400 may result in higher cost and lower agility. Such batch job patterns are best suited for migration to distributed solutions on the cloud

including:

- Data transformation and transaction processing jobs such as ETL
- Reporting and archival jobs such as incentive calculation and operational reports
- Data distribution and transmission jobs such as EDI-related file processing
- Operational data store (ODS) data sync such as ODS that is created to enable ad hoc reporting

There are two types of batch job patterns for AS400:

- **File-based processing:** On cloud, this operates in a similar manner to on-premises AS400 applications. However, once the physical files are generated, they are sent to cloud storage for long-term persistence and quick access during additional processing and analytics. Here, Hadoop along with various big data components (Spark, Hive, etc.) is leveraged to perform analytics on the stored data. The output created can be in the form of reports or normalized data to be ingested into the NoSQL database.
- **Near real-time processing:** During near real-time processing, different data streams (MQ, web services, logs, etc.) are sent directly from the AS400 to the cloud data stream platform. The real-time stream is processed and analyzed using Apache Spark Streaming and loaded into cloud-based NoSQL databases for future reporting or analytics. Additionally, data is loaded directly into a data warehouse for long-term historical reporting with dashboard tools for visualization.

Figure 3 depicts the two types of batch job patterns. The left side of the diagram shows a functional view of how these processes occur on the AS400. The right side shows the cloud architecture used to implement the new batch processes that integrate with the AS400 systems.

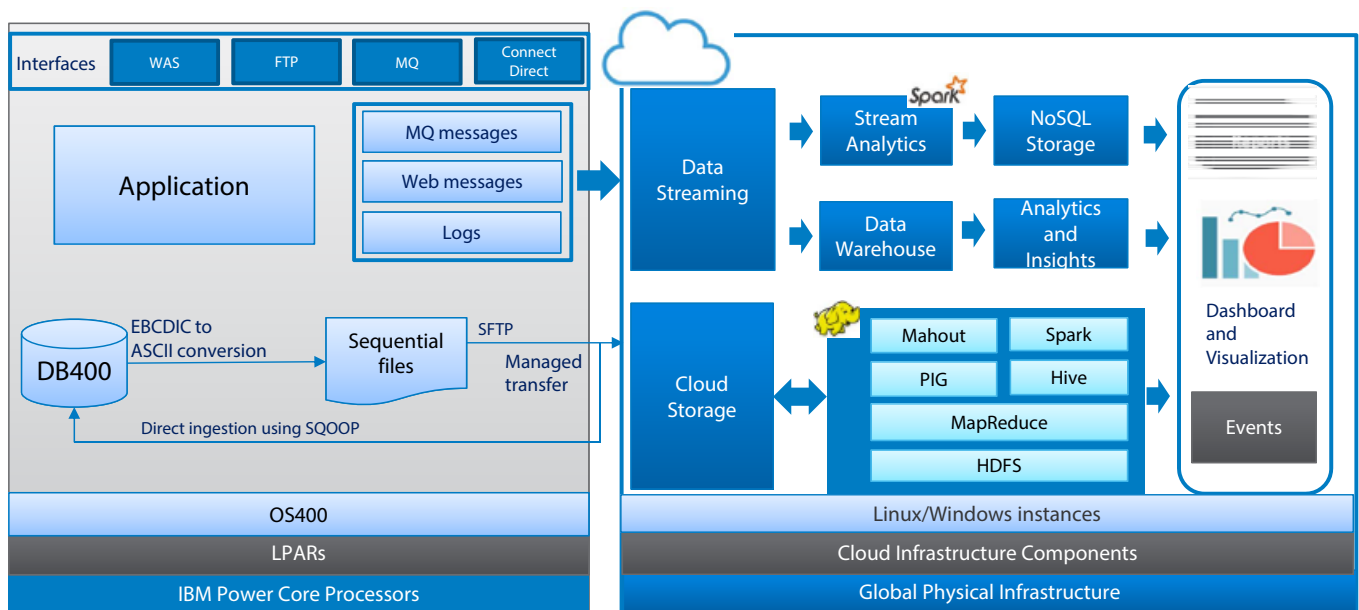
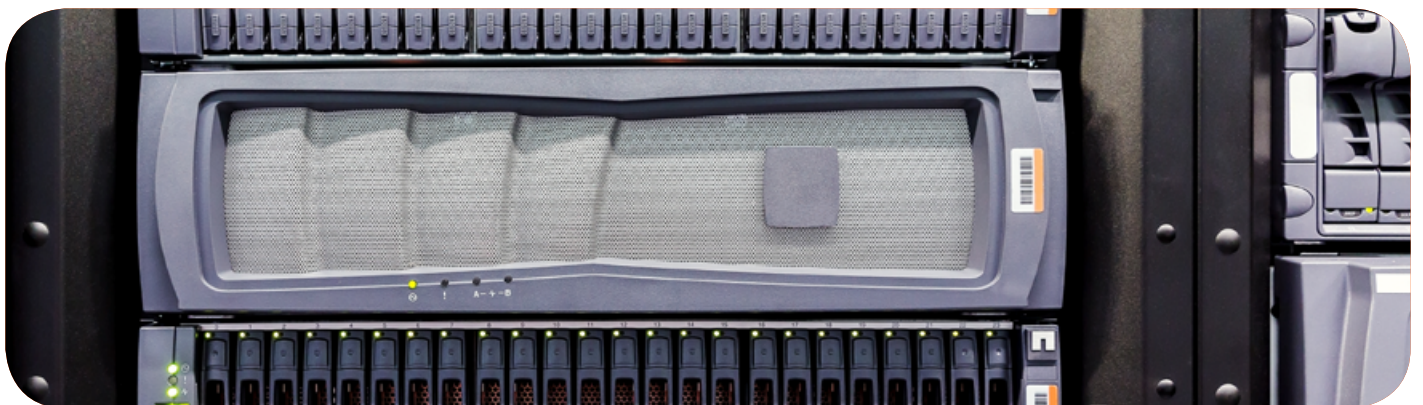


Fig 3: File-based and near real-time batch job processing on Cloud



3.2.3. Re-engineering cloud native applications

This reengineering approach is recommended when the existing AS400 application is no longer able to meet future-state business requirements or an agile target architecture. It is also considered when the application does not qualify for re-hosting during the compatibility analysis for re-hosting.

Here, a new application is created with similar performance and contains equal or enhanced functionality. Creating these

cloud native applications allows customers to take advantage of the scale, innovation and security of cloud computing. Infosys develops cloud native workloads based on the following key principles:

- Leverage open source technology such as Apache Spark, Docker Containers, etc., where possible
- Architect and implement cloud-native applications to leverage the scale and security of the cloud
- Create managed platforms that include cloud vendor managed components to reduce operational overheads
- Enable micro-services by creating API-centric applications that leverage containers, cloud container service or server-less applications like Amazon Lambda or Azure Functions in a micro-services architecture that are responsive, resilient, elastic, and asynchronous
- Ensure end-to-end security by following best-practices for security across workloads in the code and on the cloud

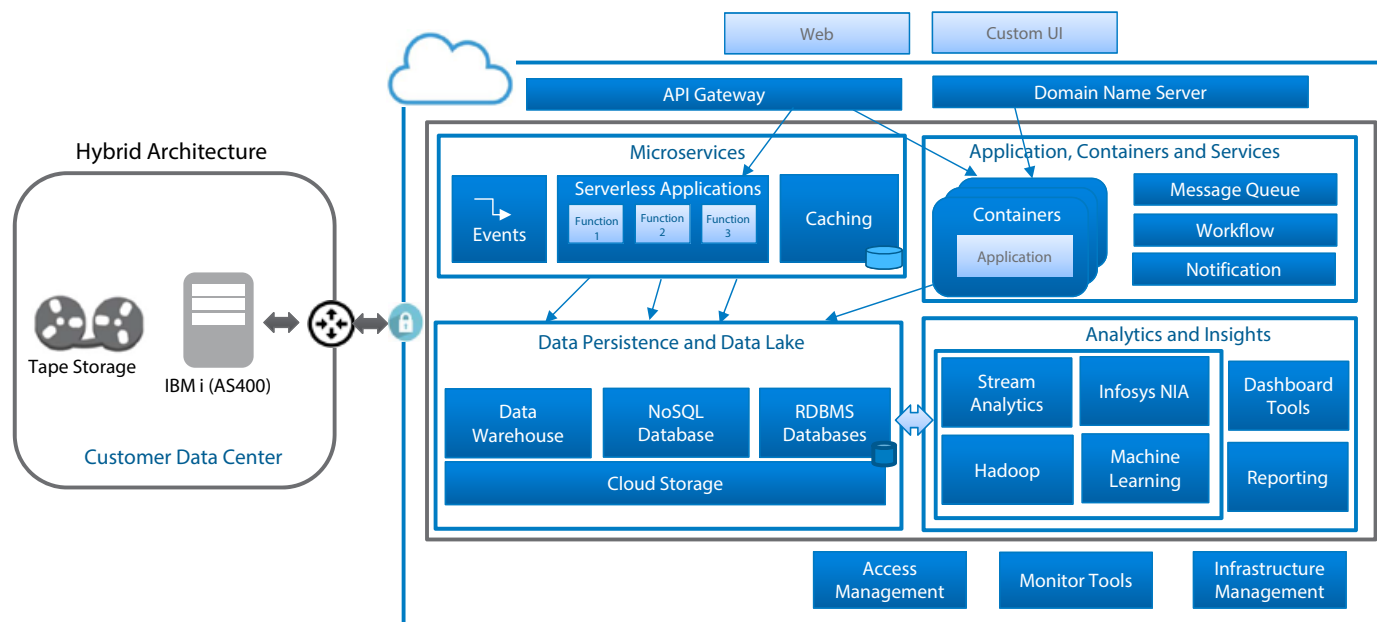


Fig 4: Functional architecture for a re-engineered AS400 application

This approach (as shown in figure 4) leverages nearly server-less and future-proof architecture of containers, micro-services, NoSQL databases, and the Infosys purposeful artificial intelligence platform, NIA. Customers that deploy this type of architecture for their re-engineered applications reduce time-to-market, increase scale, leverage world-class security, and meet their business needs more effectively. The re-engineering migration approach to cloud-native applications involves four key elements:

- Micro-services – By using a cloud-based API gateway and server-less applications like AWS Lambda/Azure Functions, workloads can run code without provisioning or managing servers while paying only for the computing time
- Application, containers and queues – The cloud container service, Docker containers and message queues enable workflows and other application-related

services to decouple complex business functionalities. The code can then be deployed and managed at scale using open source and cloud native services.

- Data persistence and data lake – Once data is in the cloud, persisting it to services such as data warehouses, NoSQL databases, managed relational databases, or cloud storage enables customers to effectively store and analyze data in ways that were previously not possible.
- Data analytics, artificial intelligence and machine learning – Once data has been persisted, customers can leverage cloud-based Hadoop, the Infosys NIA platform or cloud machine learning to get different insights from the data.

4. Renew AS400 applications

4.1. RPG upgrade

Organizations have been using IBM AS400 servers for more than 30 years with RPG as the main programming language. Over time, RPG has evolved to produce several versions ranging from RPG I to RPG IV and, more recently, free RPG. IBM has also added the integrated language environment (ILE) functionality to compile code as

module and program. Over the years, many organizations have accumulated multiple RPG versions of code in their application inventory, making these applications monolithic and difficult to maintain. Further, IBM and other modernization tool vendors have stopped supporting versions older than RPG IV.

Infosys helps customers upgrade old RPG inventory into new, free-form, optimized,

and modular RPG ILE. Our four-point RPG modernization approach upgrades RPG using tools that modularize and decouple programs, and implement ILE over applications. Modular and decoupled applications are easier to maintain and accelerate modernization initiatives. While steps 1 and 2 in this approach improve maintainability and performance, steps 3 and 4 reduce future modernization efforts.

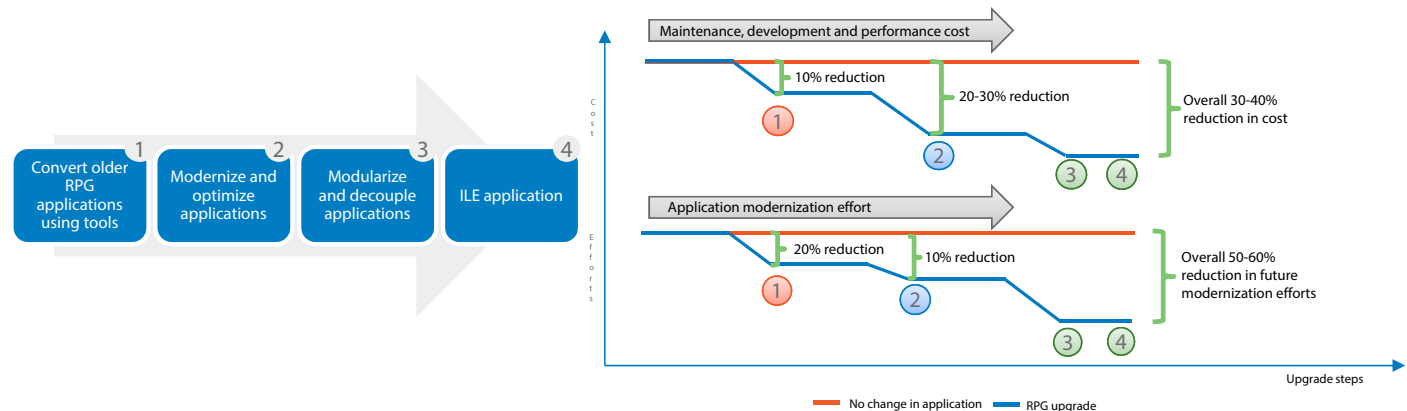


Fig 5: Long-term benefits of RPG upgrade

4.2. DB2 400 upgrade

AS400 applications, developed over span of years, are tightly coupled with their Database. Any change in database component requires recompilation of complete dependent application. The recompilation process is time consuming and error prone. Hence existing architecture reduce application agility and flexibility and increase time to market

This high dependency compromises the efficiency of business processes owing to:

- **Low flexibility:** Any change to the files mandates a recompilation of all programs that access that file, thereby compromising an application's flexibility to adopt new changes easily and quickly.
- **Poor quality:** In cases where developers omit recompiling a program, there

can be serious complications for operations and development teams during production due to high errors. Even a small deviation in the dependent application program creates issues in production. Thus, developers must invest significant time and effort to identify all the dependencies with 100% accuracy.

- **Low agility:** In such an environment where a small change request requires significant development, build and deployment effort, businesses are unable to accommodate changes quickly. Over time, applications lose their agility causing organizations to lose their competitive edge.
- **Reduced performance:** Low flexibility, quality and agility can impact performance when migrating from Data Definition Syntax to Data

Definition Language. While a Physical File processes 8000 page sizes, SQL tables process 64,000 page sizes, giving programs 8 times more data to access with faster memory. By converting DDS to DDL, organizations can give programs using buffered reads a significant and measureable performance boost.

Infosys' 'Renew' approach for DB2 400 upgrade recognizes these overwhelming technical challenges and helps organizations mitigate them by modernizing databases as well as applications, thereby achieving optimal performance, flexibility and agility. DB2 upgrade provides:

- **DDS to DDL conversion** – Infosys leverages automated tools that convert existing DDS physical files, logical files, etc., to DDL tables, views and indexes. These tools simplify the complexity of converting multi-member physical files to single table, it also handles AS400 components such as open query file, multi-format logical files, etc.
- **Application program modernization using embedded SQL** – Apart from migrating DDS files to SQL tables, Infosys also modernizes the respective application programs by using embedded SQL statements instead of file operations such as read, write, update, and chain. Tools such as Infosys Ki and the anti-pattern analyzer provide detailed views on the application and

identify target programs for change, thereby increasing speed and quality of the modernized program.

4.3. DevOps on AS400

The AS400 portfolio follows traditional ways of application development and delivery. Here, testing and fixing changes may take weeks or even months due to manual processes, limited access to test resources, difficulties in reproducing production defects, differences between development and operations environments, etc. Today, enterprises want to adopt end-to-end application enhancements quickly to stay competitive – and DevOps is way to enable this. DevOps improves collaboration between development and operations departments

and streamlines application delivery process.

Infosys has implemented an effective continuous integration/continuous delivery (CI/CD) pipeline for AS400 applications. Besides enhancing speed, quality and reliability, this approach leverages automation-driven DevOps to rapidly provision applications. By partnering with Arcad and IBM, Infosys offers a complete set of tools for AS400 DevOps. These include IBM Rational tools such as Rational Developer for I, Rational Team Concert and Rational Functional Tester as well as the complete DevOps toolset from Arcad including Observer, Skipper, drops, deliver etc., for analysis till deployment. Infosys also leverages open source tools like Jira and Selenium to complete the DevOps tool chain.

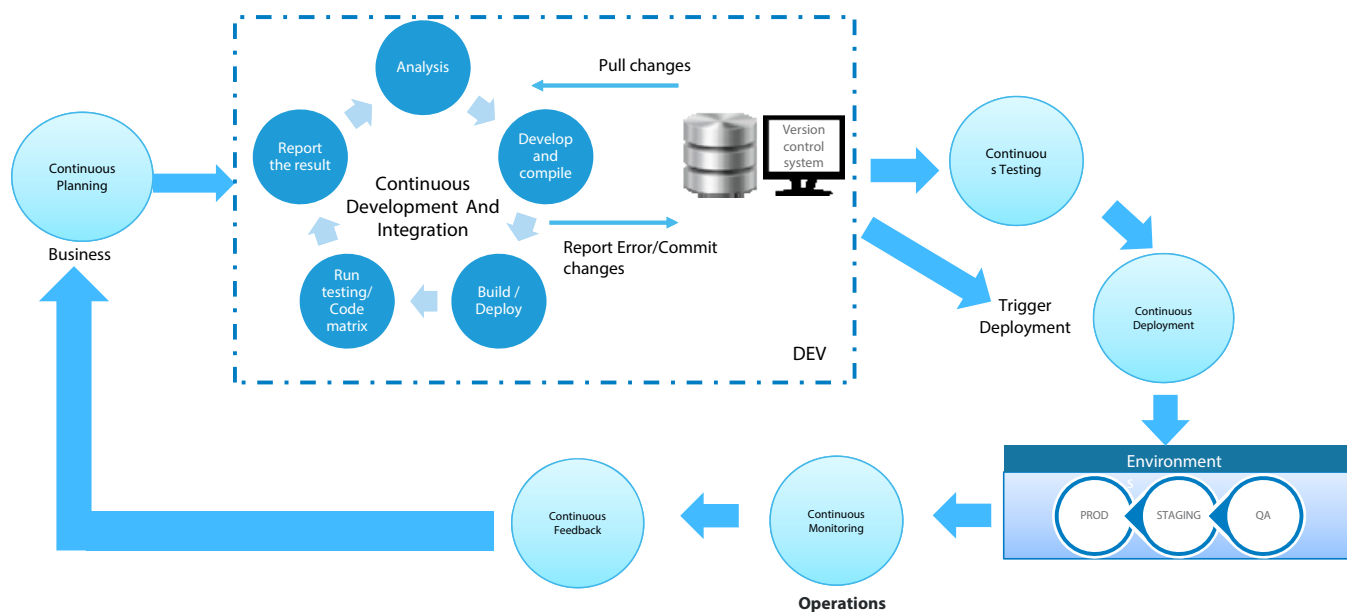


Fig 6: AS400 Devops Cycle



5. Conclusion

For many small IT departments and companies, AS400 has been the preferred choice to run workloads. As business expands and emerging technologies disrupt business processes, enterprises are looking for ways to lower the cost of supporting and maintaining AS400 applications. This, coupled with the need to enable faster application delivery, gain clear visibility into how IT impacts the business and reduce manual effort, is forcing enterprises to consider modernization initiatives. Modernizing AS400 applications involves either upgrading the applications or migrating them to cloud for seamless IT operations. However, this can be challenging owing to monolithic code that has developed over the decades, unsupported operating systems, lack of proper funding and expertise for migration, etc.

Infosys has designed a solution approach for enterprises looking for a seamless AS400 modernization journey. While the Infosys Cost Assessment Framework helps companies understand the cost of migrating versus upgrading their AS400 portfolio, the [Infosys Accelerate, Transform and Renew](#) (ART) Framework allows them to embark on their preferred solution approach. Accelerate and Transform enable companies to re-host and re-engineer their AS400 applications on cloud for higher application scalability, agility and performance. The Renew phase helps enterprises modernize their existing applications through DB2 upgrade, RPG upgrade, APIfication, and DevOps. These two frameworks, coupled with the Infosys AS400 consolidation approach, help enterprises enhance business agility, reduce manual dependencies, improve performance, lower cost, and enable IT to drive business growth.

6. About the author

Keshar Jain is a Senior Consultant with the legacy modernization practice at Infosys. He has over 10 years of experience in AS400 and related technologies. In the past, Keshar has worked on migrating applications to cloud. Currently, he helps organizations modernize their AS400 portfolio. Connect with Keshar at keshar.jain@infoys.com



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