DEVELOPING A 4R FRAMEWORK FOR APPLICATION MODERNIZATION AND CLOUD MIGRATION

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***Abstract*—This paper tackles the complex challenge of unstructured application modernization and cloud migration in enterprises by proposing a novel framework based on the 4R principles (Retire, Retain, Re-engineer, Replace). Our data-driven approach addresses key issues such as risk assessment, cost-benefit analysis, and data management, facilitating informed decision-making and minimizing migration failures. We present a user-friendly web application tool built upon this framework, enabling users to input preferences and receive tailored recommendations for application portfolio modernization and cloud migration. This interactive platform enhances efficiency and reduces risks, offering a significant step forward in guiding enterprises through the intricacies of digital transformation**

I. INTRODUCTION

A. Research Issue

In today's digital landscape, cloud computing reigns supreme. Organizations worldwide are embracing its potential to boost productivity, enhance business agility, and optimize costs. With such widespread adoption and significant financial investments, it's crucial to carefully evaluate the suitability and cost-effectiveness of migrating legacy applications to the cloud. This necessitates a structured and comprehensive approach to estimate expenses and assess viability before diving headfirst.

The process of migrating IT assets, including data and applications, from on-premises data centers to cloud computing platforms is known as cloud migration. It has many advantages, such as cost reduction, gullibility, and agility. But moving to the cloud can be a complicated process. Since, not all legacy programs are appropriate for public cloud services, moving older apps to the cloud without adequate planning might result in unforeseen expenses and delays. To avoid such pitfalls, businesses need a clear understanding of their financial requirements before embarking on this journey.

This is where an enterprise-wide strategy shines. By considering application dependencies and aligning migration plans with business goals, organizations can streamline the process and minimize costs. Adopting cloud computing at the enterprise level simplifies the IT infrastructure, strengthens the business case, and ultimately paves the way for success.

The current gap lies in the absence of a structured and comprehensive approach for enterprises modernizing applications and migrating them to the cloud. Accurately assessing risks, measuring benefits against costs, and effectively managing data throughout the migration process prove to be major hurdles. This lack of a systematic framework hinders informed decision-making and increases the risk of failure.

To address these challenges, we propose a novel approach based on the 4R principles that tackle the complexities of cloud migration head-on. By considering various cloud service models, affordability options, and potential risks, we aim to empower enterprises to make informed decisions, optimize costs, and ultimately achieve successful cloud adoption for their legacy applications.

B. Contributions:

Our team made substantial contributions across various dimensions for the completion of our project which is aimed at alleviating the challenges in application modernization and cloud migration. We meticulously crafted a structured framework grounded in the 4R principles—Retire, Retain, Re-engineer, Replace. This framework serves as a guiding compass for enterprises, facilitating informed decision-making throughout the complex process. Our data-driven approach ensures accuracy in risk assessment, benefit-cost analysis, and effective data management, fostering a systematic and well-informed strategy for migration. Moreover, we developed a user-friendly web application tool that integrates seamlessly with the framework, allowing stakeholders to input their preferences and navigate through the decision-making intricacies with ease. This tool serves as a tangible interface for enterprises to interact with the 4R principles, streamlining the application portfolio modernization journey.

II. RELATED WORK

In this paper, we explored and compared three key frameworks—Cloud Adoption Framework (CAF), Cloud Decision Framework (CDF), and Value Stream Mapping (VSM) approach—in the context of guiding organizations through the complex processes of cloud adoption, decision-making, and application portfolio optimization. Each framework addresses distinct aspects of the overall IT landscape, providing valuable insights and tools to support organizations in their journey toward efficient and effective cloud utilization and application management.

A. Cloud Adoption Framework (CAF):

The Cloud Adoption Framework stands out as a robust guide for organizations looking to embrace the transformative power of cloud computing. Encompassing the entire life cycle of cloud adoption, CAF provides a holistic approach that starts with strategic planning and extends to implementation and operational phases. By allowing organizations to assess their current cloud adoption maturity, identify improvement areas, and chart a roadmap tailored to their needs, CAF serves as a foundational resource.

CAF's strength lies in its ability to offer a panoramic view of the organization's cloud strategy. It serves as a guiding light for developing an organization-wide strategy, ensuring that the cloud becomes an integral part of the business and technology landscape.

The proposed 4R framework on the other hand is a specific tool for deciding how to migrate individual workloads. It is a relatively straightforward framework, primarily used for categorizing migration strategies for applications [1].

B. Cloud Decision Framework (CDF):

In contrast to the broad strokes of CAF, the Cloud Decision Framework (CDF) hones in on the decision-making process associated with cloud adoption. Structured around four key steps — assessing readiness, identifying requirements, evaluating providers and services, and selecting a cloud solution[5,6].

A hybrid method, in which the framework considers both technical and non-technical elements, has also been studied. The data, apps, and IT infrastructure of the company are among the technical aspects. Among the non-technical elements are the organization's spending plan, security specifications, and compliance needs. Hence, CDF provides a more nuanced approach to decision-making addressing the diverse needs of organizations [7].

The 4R framework also incorporates both technical and non-technical considerations, although it places a greater emphasis on the technical aspects that influence the process of transitioning to cloud migration.

C. Value Stream Mapping (VSM) Approach:

Value Stream Mapping (or Information-flow mapping) is a lean management technique that shows and analyses the movement of resources, data, and labor needed to provide clients with a good or service. In the context of application portfolio optimization, VSM can be adapted and applied to improve the efficiency and effectiveness of an organization's software and IT processes[9].

It involves creating a visual map that represents the current state of the application portfolio and the associated processes, creating a future state map for optimization, defining key performance indicators (KPIs), and promoting a culture of continuous improvement. VSM helps in distinguishing between activities that add value to the business and other waste ones that don't add. This analysis can highlight opportunities for optimization. This approach culminates in a future state map that envisions an optimized application portfolio closely aligned with the organization's strategic business goals[11].

The VSM approach is ideal for organizations seeking to pinpoint and eradicate bottlenecks and inefficiencies in their application portfolio. However, its implementation can pose challenges for organizations unfamiliar with VSM, and it lacks a comprehensive approach to application portfolio management.

D. Comparative Analysis:

The paper compares four frameworks and suggests the 4R Framework for straightforward application portfolio optimization. Being vendor-agnostic and versatile, it's suitable for assessing cloud migration options for various applications, including legacy, cloud-native, and hybrid, unlike VSM, CAF, and CDF which are more tailored for legacy applications.

TABLE I
COMPARISON OF CLOUD MIGRATION FRAMEWORKS

Framework	Definition	Scope	Purpose	Vendor Agnosticism	Lifecycle Stages	Flexibility and Adaptability
4R Framework	Evaluates applications based on Retire, Retain, Re-engineer, or Replace	Focuses on individual applications	Identifying the most suitable strategy for each application	Vendor-agnostic, applicable to various cloud service providers	Primarily focused on the assessment stage and decision making among the 4Rs	Provides flexibility for choosing the best-fit strategy for each application
Cloud Adoption Framework (CAF)	A Microsoft-specific methodology that provides guidance for cloud adoption	Comprehensive framework for end-to-end cloud adoption strategy	Providing a structured approach to cloud adoption across the organization	Primarily tailored for Microsoft Azure, but principles are adaptable	Covers all stages from strategy to operations	Adaptable to various organizational structures and sizes
Cloud Decision Framework (CDF)	A framework for evaluating cloud readiness and making informed decisions	Focused on decision-making for cloud migration	Assisting in decision-making during cloud migration planning	General principles applicable to multiple cloud providers	Primarily focused on decision-making during migration planning	Provides flexibility in making cloud-related decisions
Information-flow Mapping(VSM)	Visualizes and analyses the steps involved in delivering value to the customer	Analyzes the entire value delivery process	Understanding and optimizing the entire value delivery process	Independent of specific cloud providers	Primarily focused on process analysis and improvement	Flexible for analyzing and improving various processes

III. METHODOLOGY

As mentioned earlier our process is distinct from others because it includes an extensive literature review, advanced data collection techniques, in-depth data analysis, and iterative framework building. Also, this 4R model is vendor-agnostic, making it versatile for assessing cloud migration options across various application types. This distinguishes our framework from others. We assume that by employing a structured strategy rather than ad hoc methods, migration failures, and operating expenses can be significantly reduced.

We will be implementing the 4R framework for accessing and planning the cloud migration task. The implementation will consist of the following steps. The first step is to identify critical factors that influence application classification into the 4Rs. Then we must select the right R approach for each application. The four Rs represent different approaches to migrating applications to the cloud, each with its own advantages and disadvantages. The 4R's are as follows:

- **Retire:** Identify and decommission applications that are obsolete, redundant, or no longer aligned with business goals. In the context of cloud migration, this reduces the overall complexity and cost of the application portfolio, making the migration process more streamlined and easy to handle by decreasing the unnecessary load on the cloud.
- **Retain:** Keep existing applications without making significant changes. In the context of cloud migration, some applications may remain on-premise or in the existing infrastructure due to regulatory constraints, dependencies, or other business considerations.
- **Re-engineer:** Modify or re-architect an application to better align with business goals, improve performance, or leverage new technologies. In the context of cloud migration, applications are generally optimized for cloud environments, taking advantage of cloud-native features, scalability, and cost efficiency.
- **Replace:** Substitute an existing application with a new one that better meets current requirements. In the context of cloud migration, organizations may choose to replace existing applications with cloud-native alternatives to fully leverage the benefits of cloud services.

We utilized Python to extract data for our analysis, employing decision tree algorithms on common features from various enterprises for application portfolio optimization. The resulting equations effectively prevent overfitting, exhibit strong generalization, and demonstrate robust applicability across diverse datasets.

A. List of formulae for 4R Classification:

The business and technicality metrics are as follows:

$$\text{Business} = 0.5 \times \text{BC} + 0.2 \times \text{KG} + 0.3 \times \text{AS}$$
$$\text{Technicality} = \frac{AC+AM+IO+TM+DMR+SC+TR}{7}$$

Where:

$$BC : Business\ Criticality$$
$$KG : Knowledge$$
$$AS : Application\ Stability$$
$$AC : Application\ Complexity$$
$$AM : Application\ Maturity$$
$$IO : Interoperability$$
$$TM : Technology\ Maturity$$
$$DMR : Digital\ and\ Microservices\ Readiness$$
$$SC : Security$$
$$TR : Technical\ Risk$$

The decision criteria for application management are:

- **Retire:** Business < 2.5 & Technicality < 2.5
- **Retain:** Business > 2.5 & Technicality > 2.5
- **Re-engineer:** Business < 2.5 & Technicality > 2.5
- **Replace:** Business > 2.5 & Technicality < 2.5

We've incorporated and integrated these formulas into our web tool, allowing users to input their data. The tool then generates an Excel sheet that classifies applications into the 4Rs. Additionally, it provides a pie chart illustrating the distribution of applications across each of the four categories.

BC = 0.12 * AS + 0.08 * AC + 0.1 * AM + 0.09 * IO
+ 0.11 * TM + 0.1 * DMR + 0.13 * SC + 0.07 * KG + 0.05 * TR
AS = 0.1 * BC + 0.09 * AC + 0.08 * AM + 0.07 * IO
+ 0.1 * TM + 0.09 * DMR + 0.12 * SC + 0.05 * KG + 0.1 * TR
AC = 0.08 * BC + 0.09 * AS + 0.1 * AM + 0.08 * IO
+ 0.09 * TM + 0.07 * DMR + 0.11 * SC + 0.06 * KG + 0.12 * TR
AM = 0.07 * BC + 0.08 * AS + 0.09 * AC + 0.06 * IO
+ 0.08 * TM + 0.06 * DMR + 0.1 * SC + 0.05 * KG + 0.11 * TR
IO = 0.06 * BC + 0.07 * AS + 0.08 * AC + 0.09 * AM
+ 0.1 * TM + 0.11 * DMR + 0.12 * SC + 0.05 * KG + 0.07 * TR
TM = 0.09 * BC + 0.08 * AS + 0.07 * AC + 0.06 * AM
+ 0.07 * IO + 0.08 * DMR + 0.1 * SC + 0.05 * KG + 0.09 * TR
DMR = 0.05 * BC + 0.07 * AS + 0.08 * AC + 0.06 * AM
+ 0.08 * IO + 0.09 * TM + 0.1 * SC + 0.05 * KG + 0.07 * TR
SC = 0.07 * BC + 0.08 * AS + 0.09 * AC + 0.1 * AM
+ 0.07 * IO + 0.08 * TM + 0.09 * DMR + 0.05 * KG + 0.1 * TR
KG = 0.08 * BC + 0.07 * AS + 0.06 * AC + 0.05 * AM
+ 0.06 * IO + 0.07 * TM + 0.05 * DMR + 0.1 * SC + 0.08 * TR
TR = 0.09 * BC + 0.08 * AS + 0.1 * AC + 0.07 * AM
+ 0.06 * IO + 0.08 * TM + 0.07 * DMR + 0.12 * SC + 0.05 * KG

Fig. 1. To fill any empty values

In the event of missing values in the user-provided data, our system utilizes the available data points to estimate and fill in the gaps using the formulas in Fig.1.

The web tool was built using a variety of technologies for specific purposes. React.js and Express.js were employed for frontend development, providing a dynamic user interface. Python handled both data analysis and scripting tasks. MySQL Workbench managed the database, while Node.js powered the backend for robust server-side functionality. This diverse set of technologies contributed to the creation of an efficient and comprehensive web tool.

IV. EXPERIMENTATION

In experimentation, we checked the 4R model to determine the most suitable strategy for each application. Following classification, the chosen "R" can be utilized to formulate the migration plan.

We analyzed a diverse set of datasets, establishing the foundational formulas for the 4R framework.

For practical application, we selected a dataset featuring 10 applications from an enterprise, encompassing all the fields outlined in the preceding section. We then transformed this dataset into a JSON file, utilizing it as input for our web tool. After applying the formulated formulae, the results are presented within the tool itself, and displayed as an Excel sheet. Furthermore, a pie chart in Fig. 2 illustrates the distribution of applications across each "R" category.

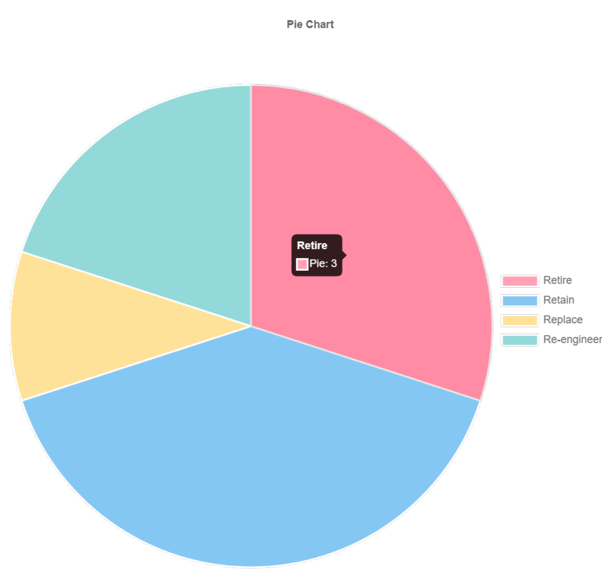

Fig. 2. Analysis of the applications

Application Name	Application Complexity	Application Maturity	Application Stability	Business Criticality	Digital and Microservices Readiness	Infrastructure	Interoperability	Knowledge Repositories	Security Adherence	Technical Risk	Technology Maturity/Debt	Inference
A1	1	2.25	2	5	5	5	5	0	5	0	5	**Retain**
A2	5	3.5	3	2.6	3	1	1	0	1	0	3	**Retire**
A3	2	3.75	1.5	4.6	5	3	5	0	5	0	5	**Retain**
A4	1	3.75	3.5	3.2	3	5	1	0	1	0	3	**Replace**
A5	5	2.5	4	4.6	5	1	1	0	5	0	5	**Retain**
A6	2	2.25	2	3	3	3	5	0	1	0	3	**Retire**
A7	1	3.75	3	5	5	5	1	0	5	0	5	**Retain**
A8	5	3.5	3.5	2.6	3	1	5	0	1	0	5	**Reengineer**
A9	2	2.25	2.5	3.2	5	3	1	0	5	0	3	**Reengineer**
A10	5	2.75	3.5	3	3	3	1	0	1	0	3	**Retire**

Fig. 3. Excel Sheet showing 4R classification for applications

We validated our findings by comparing them with results from the enterprise, which had already undergone migration using various approaches. Our framework consistently demonstrated superior outcomes.

While the presented example is illustrative, the typical scenario involves managing thousands of applications for a single vendor within a company. Our framework excels in guiding each application along the optimal migration path, offering flexibility tailored to individual application needs.

V. CONCLUSION

In summary, the research presents a novel 4R framework designed to facilitate efficient and risk-aware application modernization and cloud migration for businesses operating in today's fast-evolving digital environment. The framework consists of four main principles: Retire, Retain, Re-engineer, and Replace, which serve as a comprehensive roadmap for organizations to make well-informed decisions about their application portfolios. Underpinning the 4R framework is a robust data-driven approach that enables organizations to carefully evaluate and prioritize their applications based on factors such as risk, cost-benefit analysis, and data management.

To enhance usability and streamline the decision-making process, we have developed an intuitive web application tool that seamlessly integrates with the 4R framework. This tool allows stakeholders to input their preferences and receive customized recommendations, ensuring a more efficient and less risky application modernization journey.

A comparative analysis with prominent frameworks such as CAF, CDF, and VSM highlights the distinct advantages of the 4R framework, particularly its focus on individual applications and flexible decision-making capabilities. The rigorous methodology used to develop the framework, involving thorough data collection, in-depth analysis, and continuous refinement, sets it apart from other approaches.

Real-world dataset evaluations demonstrate the 4R framework's efficacy in delivering superior results when compared to actual migration outcomes. By guiding each application along the most suitable migration path – taking into account factors like business criticality, knowledge, application stability, and technical considerations – the 4R framework establishes itself as a vital asset for organizations managing large and diversified application portfolios. Ultimately, the 4R framework represents a significant advancement in assisting enterprises with successful application modernization and cloud adoption initiatives.

VI. CONTRIBUTIONS

Over a collaborative effort spanning three months, our five-member team meticulously conducted extensive research, implementation, evaluation, and presentation of the 4R framework. To ensure a fair distribution of tasks and contributions, specific roles were assigned to each team member.

Somanath Vamshi Thadishetty (sxt220097)
Role: Literature Review and Data Collection Phases

- Conducted an extensive literature review to identify relevant scholarly papers crucial for data collection.

• Led the data collection phase, ensuring the acquisition of comprehensive and pertinent information.

Srikar Satya (sxs230164)
Role: Data analysis and framework development

• Analyzed and elicitated the data from enterprises in Python

• Played a pivotal role in crafting formulae for the 4R framework applying decision tree algorithms etc, ensuring a solid foundation for the tool.

Manikanta Raghava Kosiganti (mxk230029)
Role: Framework and Web tool development

• Worked closely with Srikar Satya to ensure the reliability and effectiveness of the developed framework.

• Contributed to the creation of script files for the web tool's front end, enhancing the user interface.

Tanusha Nandam (txn220047)
Role: Backend Development and Database Management

• Developed the backend infrastructure of the web tool, ensuring its functionality and responsiveness.

• Oversaw the database to ensure data integrity, contributing to the robustness of the entire system.

Pratiksha Aigal (ppa220001)
Role: Testing and Documentation

• Conducted thorough testing of the developed tool to identify and address any bugs or issues.

• Validated the tool's functionality and usability, ensuring a high-quality end product.

• Took charge of documentation, including the writing of the project report, providing a comprehensive overview of the entire project.

VII. GitHub Repository Link

You can find the source code on GitHub: GitHub Repository

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