UNDERSTANDING DATA MIGRATION: PROCESSES, TYPES, AND BEST PRACTICES

Saravana Kumar Nanjappan

Sri Ramakrishna Engineering College, India

ABSTRACT

This comprehensive article explores the critical process of data migration in today's rapidly evolving digital landscape. It delves into the importance of data migration, its various types, popular tools, challenges in traditional techniques, and best practices for successful implementation. The article highlights how data migration has become a strategic imperative for organizations undergoing digital transformation, affecting business continuity, data integrity, compliance, cost management, and performance optimization. It provides insights into the growing data migration market, the shift towards cloud-based solutions, and the complexities involved in different migration scenarios, including legacy system upgrades, cloud transitions, and post-merger integrations.

Saravana Kumar Nanjappan

Introduction

In today's rapidly evolving digital landscape, organizations frequently find themselves needing to transfer data between systems or update data formats to keep pace with technological advancements. This process, known as data migration, is a critical operation that requires careful planning and execution to ensure data integrity and business continuity.

The importance of data migration has grown exponentially in recent years, driven by the digital transformation initiatives across industries. According to a report by Marketsand Markets, the global data migration market size is expected to grow from USD 8.8 billion in 2021 to USD 16.7 billion by 2026, at a Compound Annual Growth Rate (CAGR) of 13.8% during the forecast period [1]. This substantial growth highlights the increasing demand for efficient data migration solutions as organizations modernize their IT infrastructures.

The value and significance of data in today's economy cannot be overstated. As The Economist aptly pointed out in 2017, data has surpassed oil as the world's most valuable resource [2]. This paradigm shift has profound implications for businesses across all sectors. The ability to effectively manage, move, and leverage data has become a critical competitive advantage. In this context, data migration is not just a technical necessity but a strategic imperative that can directly impact a company's market position and long-term success.

Data migration is not merely a technical exercise; it's a complex process that intertwines with various aspects of business operations:

1. Business Continuity: During migration, organizations must ensure that their day-to-day operations continue uninterrupted. This often requires careful planning and execution, sometimes involving phased migrations or parallel running of old and new systems.
2. Data Integrity: Maintaining the accuracy and consistency of data throughout the migration process is paramount. Even small errors or inconsistencies can lead to significant issues in business operations or decision-making processes.
3. Compliance and Security: With the introduction of stringent data protection regulations like GDPR and CCPA, organizations must ensure that their data migration processes comply with legal requirements. This includes maintaining data privacy, implementing appropriate security measures, and ensuring the right to be forgotten is preserved even during migration.
4. Cost Management: While necessary, data migration can be an expensive undertaking. Organizations need to carefully balance the costs of migration against the potential benefits and risks of not migrating.
5. Performance Optimization: Post-migration, the new system should ideally offer improved performance. This could mean faster data retrieval times, better data analytics capabilities, or enhanced user experiences. Achieving these improvements often requires not just moving data, but also optimizing its structure and storage.

As we delve deeper into the world of data migration, we'll explore various types of migration strategies, common challenges faced by organizations, and best practices that can be adopted to ensure successful outcomes. Understanding these aspects is crucial for any organization embarking on a data migration journey, as it can mean the difference between a smooth transition that adds value to the business and a costly, disruptive process that hampers operations.

Why Perform Data Migration?

Organizations embark on data migration initiatives for various compelling reasons, each driven by the need to enhance operational efficiency, reduce costs, or adapt to changing business landscapes. Let's explore these motivations in detail:

Upgrading from Legacy Systems to Modern Cloud Storage

One of the primary drivers for data migration is the transition from outdated legacy systems to modern cloud-based infrastructure. Legacy systems, while once cutting-edge, can become bottlenecks in an organization's digital transformation journey. A study by Forrester Research found that modernizing legacy systems is a top priority for 74% of businesses, with cloud migration being a key component of this modernization effort [3].

Cloud migration offers numerous benefits:

- Scalability: Cloud systems can easily scale up or down based on demand.
- Cost-efficiency: Pay-as-you-go models often result in significant cost savings.
- Enhanced security: Cloud providers typically offer robust security measures.
- Improved accessibility: Data can be accessed from anywhere with an internet connection.

For instance, Capital One, a major financial services company, migrated from its on-premises data centers to AWS, resulting in increased agility, reduced time-to-market for new products, and significant cost savings.

Ensuring Data Compatibility with Updated Applications

As organizations upgrade their software applications, ensuring data compatibility becomes crucial. Modern applications often require data in specific formats or structures to function optimally. Data migration in this context involves not just moving data, but also transforming it to meet new requirements.

For example, when a company upgrades its Enterprise Resource Planning (ERP) system, it might need to restructure financial and operational data to take advantage of new features like real-time analytics or AI-powered forecasting. This process often involves data cleansing, deduplication, and reformatting.

Moving Between Different Cloud Storage Systems for Cost Optimization

With the proliferation of cloud service providers, organizations are increasingly moving data between different cloud platforms to optimize costs and leverage specific features. This type of migration, known as cloud-to-cloud migration, has become more common as businesses seek to avoid vendor lock-in and take advantage of competitive pricing and services.

For instance, a company might move from one cloud provider to another to take advantage of better pricing tiers, improved performance in certain geographical regions, or specific features that align better with their evolving needs. The multi-cloud strategy has gained popularity, with Gartner predicting that by 2025, over 90% of enterprises will pursue a multi-cloud infrastructure strategy [3].

Addressing Data Integration Needs Following Mergers and Acquisitions

Mergers and acquisitions (M&As) often necessitate large-scale data migration efforts. When companies combine, they need to consolidate their data assets to achieve operational synergies and gain a unified view of the business. This process can be complex, involving the integration of disparate data formats, elimination of redundancies, and ensuring compliance with data protection regulations.

A study by Deloitte found that 63% of companies undertaking M&A activity experienced data migration challenges, highlighting the critical nature of this process in corporate integrations [4].

Data migration in M&A scenarios typically involves:

- Identifying and cataloging all relevant data assets
- Mapping data between different systems
- Ensuring data quality and consistency
- Managing data privacy and regulatory compliance
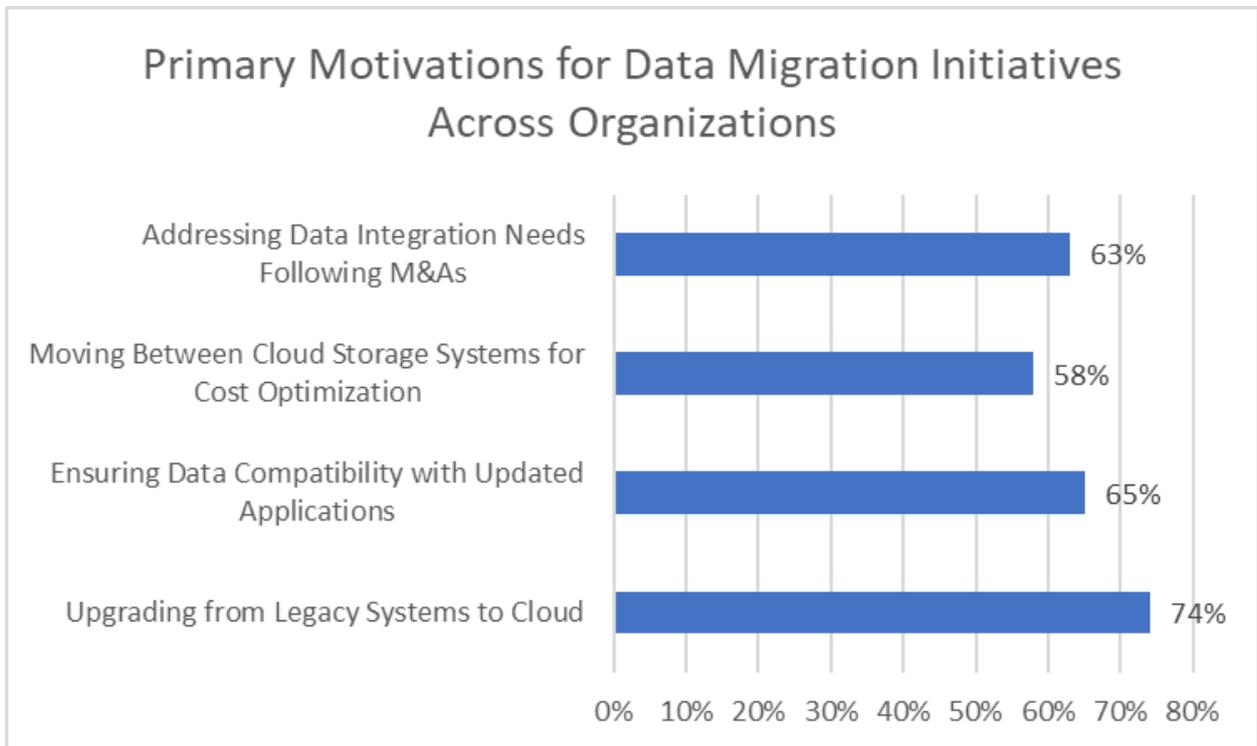- Integrating data into a unified system for the combined entity

Fig. 1: Key Drivers of Data Migration Projects in the Modern Business Landscape [3, 4]

Types of Data Migration

Data migration comes in various forms, each addressing specific organizational needs and technological shifts. Understanding these types is crucial for planning and executing successful data migration projects. Let's explore each type in detail:

Storage Migration

Storage migration involves moving data from one storage format or system to another. This type of migration is often necessitated by the need to upgrade legacy storage systems or to make data compatible with more advanced applications.

According to a study by IDC, by 2025, the global datasphere will grow to 175 zettabytes, and nearly 30% of this data will need real-time processing [5]. This explosive growth is driving organizations to adopt more efficient and scalable storage solutions, making storage migration a critical process.

Key considerations for storage migration include:

- Data volume and growth projections
- Performance requirements of the new storage system
- Data access patterns and frequency
- Compatibility with existing and future applications

For example, a healthcare organization might migrate patient records from an outdated file system to a modern, HIPAA-compliant cloud storage solution to improve data accessibility and security.

On-Premises to Cloud Migration

As organizations increasingly leverage cloud services, moving data from on-premises systems to cloud storage has become a common practice. This approach offers numerous benefits, including scalability, flexibility, and cost-effectiveness.

A survey by O'Reilly found that 90% of organizations are using cloud computing, with 48% planning to migrate 50% or more of their applications to the cloud in the coming year [6]. This trend underscores the importance of on-premises to cloud migration.

Benefits of on-premises to cloud migration include:

- Reduced infrastructure maintenance costs
- Improved scalability and flexibility
- Enhanced disaster recovery capabilities
- Access to advanced cloud-native services and analytics

For instance, Netflix's migration of its entire infrastructure to Amazon Web Services (AWS) allowed the company to scale its services globally and handle unpredictable streaming demands more efficiently.

Cloud-to-Cloud Migration

Cloud-to-cloud migration involves transferring data between different cloud storage systems. This type of migration is typically driven by cost reduction efforts, the need to align with new company standards, or to take advantage of specific features offered by different cloud providers.

The multi-cloud strategy has gained significant traction. According to Flexera's 2022 State of the Cloud Report, 89% of respondents have a multi-cloud strategy, with 80% taking a hybrid approach (combining public and private clouds) [6]. This trend is fueling the need for efficient cloud-to-cloud migration processes.

Reasons for cloud-to-cloud migration include:

- Optimizing costs by leveraging competitive pricing
- Avoiding vendor lock-in
- Accessing specialized services offered by different providers
- Improving performance and reducing latency in specific geographical regions

For example, a multinational corporation might distribute its data across multiple cloud providers to optimize performance and comply with data residency requirements in different countries.

Application or Process Migration

When organizations upgrade existing applications or move them to new computing systems, the associated data must also be migrated to ensure alignment with the new application's requirements. This type of migration often involves data transformation to fit new data models or structures.

Application migration is a key component of digital transformation initiatives. The Flexera report indicates that 59% of respondents plan to focus on cloud migration in the coming year, highlighting the importance of this process [6].

Key aspects of application or process migration include:

- Data mapping between old and new systems
- Data cleansing and normalization
- Testing and validation of data in the new application
- Managing application dependencies and integrations

An example of this type of migration is when a company upgrades its Customer Relationship Management (CRM) system, necessitating the migration and transformation of customer data to fit the new CRM's data model and take advantage of new features.

Migration Triggered by Reorganizations, Mergers, and Acquisitions

Organizational changes, such as mergers and acquisitions (M&As), often necessitate data transformation to meet new standards or integrate data from merged entities. This type of migration is critical for achieving operational synergies and gaining a unified view of the combined business.

While the Flexera report doesn't specifically address M&A-driven migrations, it does highlight the growing complexity of cloud environments, with organizations using an average of 2.6 public clouds and 2.7 private clouds [6]. This complexity can be further compounded during M&A activities, making efficient data migration strategies crucial.

Challenges in M&A-driven data migration include:

- Reconciling different data standards and formats
- Ensuring data quality and consistency across merged entities
- Managing data privacy and regulatory compliance
- Integrating disparate systems and databases

For instance, when large corporations merge, they often need to consolidate multiple cloud environments and on-premises systems, requiring a comprehensive data migration strategy.

In conclusion, understanding these different types of data migration is crucial for organizations as they navigate the complex landscape of digital transformation, cloud adoption, and corporate restructuring. Each type of migration presents unique challenges and opportunities, requiring careful planning and execution to ensure success.

Type of Data Migration	Percentage of Organizations
Storage Migration	30%
On-Premises to Cloud Migration	48%
Cloud-to-Cloud Migration	89%
Application or Process Migration	59%
M&A-Triggered Migration	25%

Table 1: Prevalence of Different Data Migration Types Across Organizations [5, 6]

Popular Data Migration Tools

As organizations increasingly recognize the importance of efficient data migration, a variety of tools have emerged to facilitate this process. These tools range from cloud-native services offered by major providers to custom in-house solutions. Let's explore some of the most popular data migration tools in detail:

AWS Data Migration Service (DMS)

Amazon Web Services (AWS) Data Migration Service is a cloud-based solution designed to help organizations migrate databases to AWS quickly and securely. It supports both homogeneous migrations (such as Oracle to Oracle) and heterogeneous migrations (such as Oracle to Amazon Aurora).

Key features of AWS DMS include:

- Continuous data replication with minimal downtime
- Support for widely used database engines
- Built-in data validation to ensure data integrity

- Integration with other AWS services for comprehensive migration solutions

According to a report by Forrester Research, AWS is recognized as a leader in database migration services, with its comprehensive toolset and robust ecosystem being significant factors [7]. This underscores the popularity and effectiveness of AWS DMS in the market.

Use case: A large e-commerce company migrated its on-premises Oracle database to Amazon Aurora using AWS DMS, completing the migration of 200TB of data with less than 30 minutes of downtime, resulting in improved performance and reduced operational costs.

Azure Data Migration Service

Microsoft's Azure Data Migration Service is another cloud-based tool designed to streamline database migrations to Azure's data platforms. It offers a comprehensive approach to data migration, covering assessment, implementation, and ongoing monitoring.

Key features of Azure Data Migration Service include:

- Support for both online (minimal downtime) and offline migrations
- Compatibility with various source databases, including SQL Server, Oracle, and MySQL
- Integration with Azure Database Migration Assistant for pre-migration assessments
- Scalability to handle large-scale database migrations

The adoption of Azure services, including its migration tools, has been growing rapidly. According to Microsoft's FY21 Q4 results, Azure revenue grew by 51% year-over-year [8], indicating the increasing popularity of Azure's cloud services, including its data migration tools.

Use case: A healthcare provider successfully migrated its on-premises SQL Server databases to Azure SQL Database using Azure Data Migration Service, improving data security and compliance with HIPAA regulations while reducing infrastructure management overhead.

Manual/In-House Data Migration (for custom processes)

While cloud-based tools offer numerous advantages, some organizations opt for manual or in-house data migration solutions, especially when dealing with unique or highly customized data structures and processes.

Reasons for choosing manual/in-house migration include:

- Complete control over the migration process
- Ability to handle unique data formats or legacy systems not supported by off-the-shelf tools
- Customization of the migration process to meet specific business requirements
- Mitigation of data security concerns by keeping the process entirely in-house

However, manual migrations can be time-consuming and prone to errors if not carefully managed. Organizations choosing this route often develop custom scripts and tools tailored to their specific needs.

Use case: A government agency with highly sensitive data opted for an in-house migration solution when moving from a legacy mainframe system to a modern, secure database. This approach allowed them to maintain strict control over data handling and ensure compliance with stringent security protocols.

The importance of custom approaches in data migration is highlighted in a survey by Forrester Research, which found that 62% of organizations consider customization capabilities as a critical factor when selecting data integration and migration tools [7]. This emphasizes the continued relevance of tailored solutions alongside commercial tools.
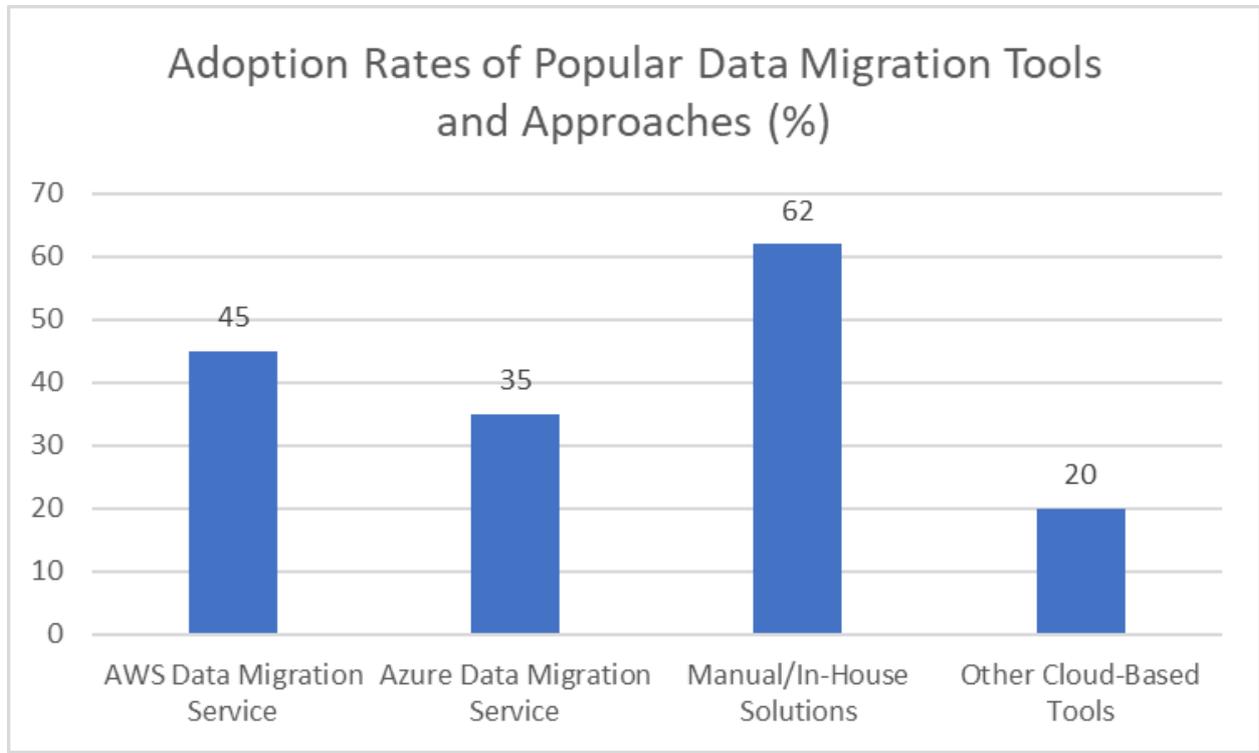

Fig. 2: Market Share of Data Migration Solutions in Enterprise Environments [7, 8]

Choosing the Right Tool

Selecting the appropriate data migration tool depends on various factors, including:

- Source and target database systems
- Volume and complexity of data
- Downtime tolerance
- In-house expertise
- Budget constraints
- Compliance and security requirements

Organizations often use a combination of tools and approaches to address different aspects of their data migration needs. For instance, they might use AWS DMS for database migration while employing custom scripts for ETL (Extract, Transform, Load) processes.

As data volumes continue to grow and cloud adoption accelerates, the importance of efficient data migration tools cannot be overstated. Whether opting for cloud-native services or developing custom solutions, organizations must carefully evaluate their options to ensure successful data migrations that support their broader digital transformation goals.

Challenges in Traditional Data Migration Techniques

While data migration is crucial for organizations looking to modernize their infrastructure or adapt to changing business needs, traditional migration techniques often come with significant challenges. These challenges can lead to project delays, increased costs, and in some cases, data loss or corruption. Let's explore some of the most common challenges in detail:

Mismatched Data Formats

One of the primary challenges in data migration is dealing with mismatched data formats between source and target systems. This issue is particularly prevalent when migrating from legacy systems to modern databases or when consolidating data from multiple sources.

According to a survey by Experian, 95% of organizations say that poor data quality undermines their business performance [9]. While this statistic isn't specific to data migration, it underscores the critical impact of data quality issues, which are often exacerbated during migration processes.

Challenges associated with mismatched data formats include:

- Incompatible data types (e.g., storing dates as strings vs. date objects)
- Differences in character encoding (e.g., ASCII vs. UTF-8)
- Variations in field lengths and precision (e.g., floating-point number precision)
- Inconsistent naming conventions and data structures

To address this challenge, organizations often need to implement complex data transformation processes, which can be time-consuming and error-prone if not managed carefully.

Loss of Incremental Data During Migration

In many cases, the source system continues to receive and process new data while the migration is in progress. This situation can lead to the loss of incremental data if not properly managed.

A study by ITIC found that 98% of organizations say a single hour of downtime costs over $100,000 [10]. While this isn't specific to data migration, it highlights the critical importance of minimizing downtime and ensuring that all data, including incremental updates, is properly migrated.

Key issues related to incremental data loss include:

- Inconsistencies between source and target systems
- Missed transactions or updates
- Potential for data conflicts and integrity issues
- Extended downtime to reconcile data discrepancies

To mitigate this challenge, organizations often implement change data capture (CDC) mechanisms or perform final delta migrations to ensure all incremental changes are captured.

Data Truncation Issues

Data truncation occurs when the target system has more restrictive field length limitations than the source system. This can result in the loss of important information if not properly handled.

While specific statistics on data truncation are scarce, the Experian study mentioned earlier found that 83% of organizations see data as an integral part of forming a business strategy [9]. This emphasizes the importance of maintaining data integrity during migration, including preventing truncation issues.

Common scenarios where data truncation can occur include:

- Moving from systems with unrestricted text fields to those with character limits
- Migrating from databases with larger numeric precision to those with smaller precision
- Transferring data between systems with different date/time format specifications

Data truncation can lead to serious consequences, including loss of critical information, data integrity issues, and potential system failures.

Inadequate Test Coverage

Comprehensive testing is crucial for successful data migration, yet many organizations struggle with inadequate test coverage. This can result in undetected errors that only surface after the migration is complete, potentially leading to significant business disruptions.

The importance of thorough testing is underscored by a finding from the ITIC study, which states that 51% of organizations need 1 to 4 hours to recover from unplanned downtime [10]. Inadequate testing can lead to such downtime, emphasizing the need for comprehensive test coverage.

Challenges related to inadequate test coverage include:

- Difficulty in creating representative test data sets
- Limited resources for thorough testing
- Complexity in simulating all possible data scenarios
- Time constraints leading to rushed or incomplete testing

Inadequate testing can result in:

- Undetected data quality issues
- Functional problems in the target system
- Performance issues due to unforeseen data patterns
- Compliance risks if regulatory requirements are not met

To address this challenge, organizations need to invest in comprehensive testing strategies, including automated testing tools, realistic data sampling, and thorough validation processes.

Challenge	Percentage of Organizations Affected
Mismatched Data Formats	95%
Loss of Incremental Data	98%
Data Truncation Issues	83%
Inadequate Test Coverage	51%

Table 2: Prevalence of Key Challenges in Traditional Data Migration Processes [9, 10]

Best Practices for Successful Data Migration

Successful data migration is crucial for organizations undergoing digital transformation, system upgrades, or consolidation efforts. By following established best practices, companies can minimize risks, reduce downtime, and ensure data integrity throughout the migration process. Let's explore these best practices in detail:

Data Assessment

Conducting thorough data assessments is a critical first step in any data migration project. This process involves comprehensive audits to understand data processing requirements, assess data quality, and identify potential migration challenges.

Research by Thalheim and Wang emphasizes the importance of data quality assessment in migration projects, stating that "data quality problems are one of the main reasons for delays and failures in data migration projects" [11]. This underscores the critical role of thorough data assessment in ensuring project success.

Key components of data assessment include:

- Data profiling to understand the structure, content, and quality of source data
- Identifying data dependencies and relationships
- Assessing data volumes and growth patterns
- Evaluating data security and compliance requirements

Example: A large financial institution conducting a data assessment before migrating to a new CRM system discovered significant inconsistencies in customer data formats across different departments. This discovery allowed them to implement standardization procedures before migration, significantly improving the quality and usability of data in the new system.

Migration Planning

Effective migration planning involves defining the project scope, budget, tools, and strategies. It's also crucial to choose the right migration partner to ensure regulatory compliance and technical expertise.

Matthes highlight the importance of comprehensive planning in their study on enterprise architecture management, noting that "a systematic approach to planning and executing data migrations is essential for managing complexity and ensuring alignment with business goals" [12]. Their research emphasizes the need for detailed planning to address potential challenges proactively.

Key elements of migration planning include:

- Defining clear project objectives and success criteria
- Selecting appropriate migration tools and technologies
- Developing a detailed project timeline with milestones
- Identifying and mitigating potential risks
- Establishing a governance structure for decision-making

Example: A healthcare provider planning to migrate patient records to a cloud-based system created a detailed migration plan that included strategies for ensuring HIPAA compliance, data encryption protocols, and a phased migration approach to minimize disruption to patient care.

Data Backup

Implementing a comprehensive backup plan for all business data before initiating migration is a crucial safeguard against data loss or corruption during the migration process.

The importance of data backup is underscored by Thalheim and Wang, who state that "data preservation and the ability to roll back changes are critical components of any data migration strategy" [11]. This highlights the need for robust backup procedures to mitigate risks during migration.

Best practices for data backup include:

- Creating full backups of all data before migration
- Implementing redundant backup systems
- Testing backup and restore procedures
- Ensuring backups are securely stored and easily accessible

Example: A manufacturing company preparing to migrate its production data to a new ERP system implemented a multi-tiered backup strategy, including on-site backups, off-site replications, and cloud-based disaster recovery solutions. This comprehensive approach provided multiple layers of protection against data loss during the migration process.

Post-Migration Validation

Continuous testing and monitoring of target systems after migration is essential to identify and resolve any issues promptly. This ongoing validation ensures that the migrated data is accurate, complete, and functioning as expected in the new environment.

Matthes emphasize the importance of post-migration validation in their research, stating that "continuous monitoring and evaluation of migrated systems are crucial for ensuring long-term success and alignment with business objectives" [12]. Their study highlights the need for comprehensive validation processes to maintain data quality and system performance.

Key aspects of post-migration validation include:

- Automated data reconciliation between source and target systems
- Performance testing to ensure system responsiveness
- User acceptance testing to verify functionality
- Continuous monitoring for data integrity and system stability

Example: An e-commerce company that migrated its customer database to a new cloud platform implemented an automated daily reconciliation process to compare transaction data between the old and new systems. This approach allowed them to quickly identify and resolve discrepancies, ensuring data accuracy and maintaining customer trust.

Conclusion

Data migration emerges as a crucial yet complex process in the modern business environment, driven by the need for digital transformation and the growing value of data as a strategic asset. The article underscores the importance of careful planning, thorough data assessment, robust backup strategies, and continuous post-migration validation to ensure successful outcomes. As organizations navigate the challenges of mismatched data formats, incremental data loss, truncation issues, and inadequate testing, the adoption of best practices and appropriate tools becomes paramount. With the increasing volume and complexity of data, coupled with the accelerating shift towards cloud-based infrastructures, mastering effective data migration strategies is essential for organizations to maintain competitiveness, optimize performance, and drive long-term success in an increasingly data-centric business landscape.

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