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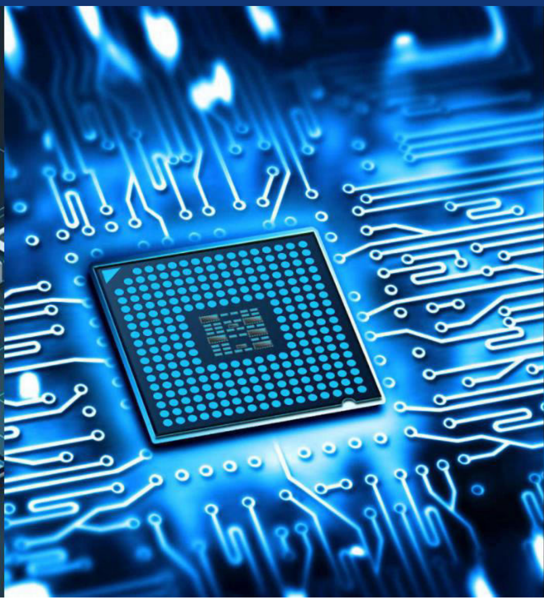


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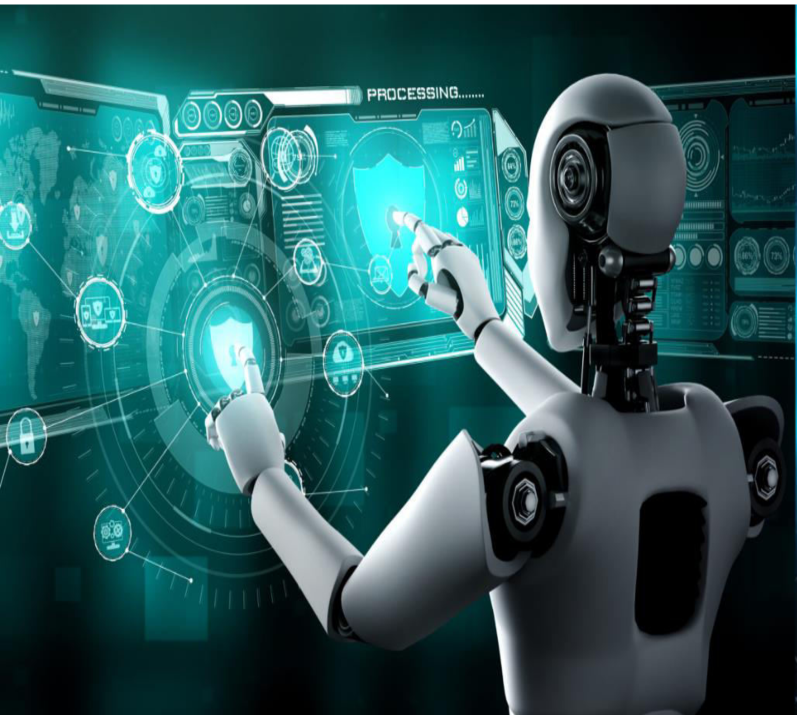

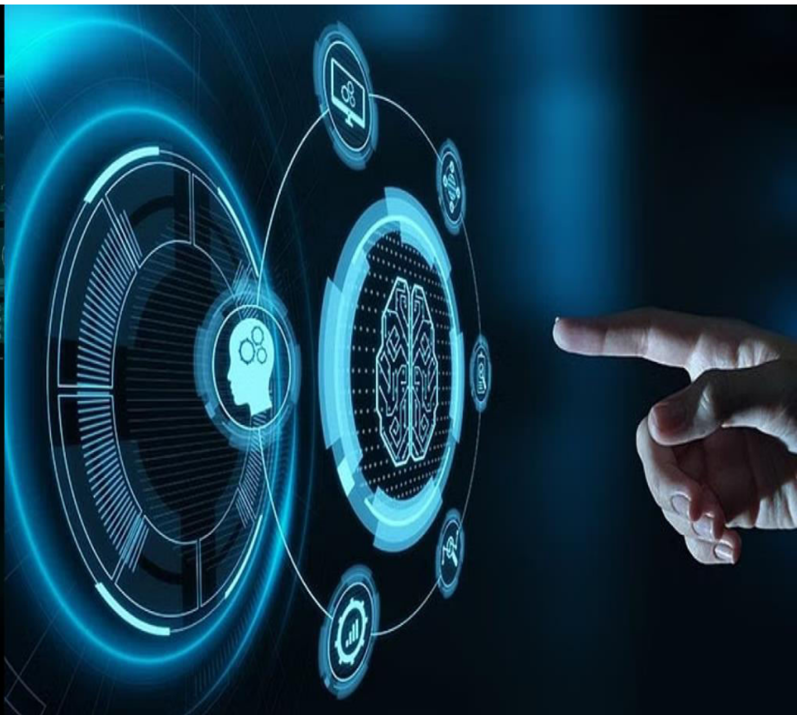

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Leveraging Integrated Master Data and Claims Pipelines to Transform Medication Synchronization in Pharmacy Services

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ABSTRACT: Rx Sync is a data-focused initiative designed to enhance pharmacy services with improved patient graduation from a medication-taking behavior using data aggregation and analytics; it draws data from many sources, compiling it into a discrete, more effective Product Data Store (PDS). The end product is trustworthy patient profiles complete with layers of data management processes to ensure consistent accuracy of data and linkage of data into actual profiles, and data management processes. The work has resulted in a historic reduction of short-acting opioid prescriptions by 31% and since then has also realized operational efficiencies for improved refill bundling, substitution generics, and home delivery possibilities with potential implications for cost and health outcomes. Utilizing scalable ETL standards and distributed computing technologies, Rx Sync was also able to sustain engagement to address challenges from data silos and data types/processes of designated larger datasets and to still be respectful of patient preferences. The timing of continuous update and feedback loops has also enhanced Rx Sync's performance and value as a project showcasing how the healthcare sector continues to need to transition and embrace Big Data strategies for ultimately higher value patient-centered care and pharmacy operations improvement overall.

KEYWORDS: Pharmacy Services, Data Aggregation, Product Data Store (PDS), ETL, Big Data Strategies

I. INTRODUCTION

Sync platforms and technologies, like rsync and RxDB, have their particular advantages for syncing and migrating data sets especially for data related to Rx. Rx technologies allow for incremental updates so only changed data gets sent (as opposed to bulk data movement in most traditional technologies), improving efficiency of migration and backup strategy while minimizing network impact. Newer sync technologies like NetApp Cloud Sync and AWS DataSync are also capable of leveraging parallel processing and optimized bandwidth to provide faster sync of large Rx data sets over bulk data movement, as many traditional technologies rely on. These new sync technologies (as mentioned) are useful for regulated industries, including healthcare, because they provide scalability for larger data sets, encrypted data, scheduled transfer (i.e. automated collection of Rx data sets), and the ability to monitor the transfer. Sync services can also connect from different origins and establish a connection without custom programming. Sync services can also provide data transport encryption, facilitate automatic error recovery, and establish ingestion pipelines into cloud analytic service environments where Rx data remains compatible applications (e.g., live analytics legend [1]).

In contrast, RxDB replication has many advantages as well as traditional sync technologies, mainly in terms of offline flexibility as well as the ability to work in real-time. This is in contrast to their more basic counterparts like rsync, who offer bulk data transfer but not in an application aware way when syncing data.RxDB serves to provide users an offline-first architecture to allow data to be accessed locally with the ability to sync when re-connected, especially when the application will create solutions to care delivery (i.e., healthcare). It also has the capacity for bidirectionalsync, while also allowing an application to allow a real-time state change with either version state history or conflict resolution, for flexibility across devices and users. With the NoSQL database and GraphQL API capabilities, RxDB enables integrations through APIs, thus not needing specialized adapters. Partial/Filtered sync means only the specific data an application requires the user is synced based on permissions, which optimizes storag and bandwidth. The local-first method improves user experience by providing data to the user quickly without the synchronous input time which will be limited if offline; it can also perform peer-to-peer replication and manage multiple app instances which provides secure, direct data movement. In comparison, past sync tools do not require the integrity of the

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application state, allow limited offline awareness, are real-time, claim to detect conflicts in limited scenarios, and are flexible with loss of network [2].

Rx Sync as a data-first platform seeks to minimize costs while also alleged to improve services given to you as the patient and provider. This is done by giving you daily snapshots (full and increments) data from a different data stores (such as claims, prescription data, insurance subscriber lists) with robust features and APIs. The ingestion pipeline is standard pipeline and takes multiple formats. There is no problems with ingesting external data. Raw data is ingested into a data lake and is "cleaned up" via hygiene process (linking patients pharmacy history under the SSID crosswalk). This leads to well-formed Product Data Stores (PDS) that present a holistic view of patients insurance and pharmacy. The PDS data set is processed through the Master Data Management (MDM) system; these data will be clustered using patient clinical characteristics, type of meds, patient history, refill pattern within patient history (structured data frame models) - giving the ability to have a more sophisticated/advanced model that provides patient opportunities (reduce pharmacy visits (to consolidated refills), changed process to home delivery, generic meds alternatives to cost saving). Once every aspect of data collection, hygiene, and diligence is brought into the Rx Sync platform, pharmacy practice are optimized with value added solutions for the provider and patient while delivering and optimizing their clinical health outcomes and saving money. [3]

The specific timelines for the Rx Sync meeting are sequenced by an array of detail with timelines of relative 10-12 months following the interactions of the timeline in terms of data intensive processes. It begins with the planning and initiation of the project where goals, scope of work, and deliverables are determined, identified stakeholders are engaged, and included in risk assessments for shared outcomes. The following phase is capacity development of a data ingestion application, including creating API endpoints and linkages for various data sources up to and including establishing a data lake for raw data. For the next several months, standardization and data hygiene measures are prioritized, with guidelines for data formatting and automated workflows followed to standardize unstructured data captured during the pharmacy dispensing process. Linking and crosswalks occur at the point of patient prescription history.As the project moves forward, product data stores are created to store datasets for additional analysis, which leads to master data management to classify the data by multiple factors that are related to the patients. The analysis and modeling of the opportunity are then made and emphasis is given to identify savings opportunities and provide actionable insights regarding medication management. Prior to finalizing the deployment of the analytics outputs and of the Sync platform, user acceptance testing and optimization take place, and monitoring is conducted when analyzing for data accuracy and the performance of the platform. Finalizing with ongoing support and updates to the project and addressing issues encountered and improvements with features occurs once the project is completed. Throughout the entire timeline of services used to support this project, milestones are developed in an incremental and iterative manner in order to maintain quality and mitigate risk while being in alignment with the goals of patient service cost savings [4].

The Rx Sync system allows both patients and clinicians to collaboratively view and approve medication recommendations for medication management, relying on an internet-based prescription management portal. Upon approval, pharmacist obtain and have the information needed to implement actions such as group multiple prescriptions to be filled or delivered through either a pharmacy delivery service from the drug store or delivered from the patient prescribed medication manufacturer. This also flushes out the opportunity for delay by creating a virtuous feedback loop, because whether the shift action succeeds or does not, feedback is once again sent back to the Sync platform to avoid recommend the same redundancies. Patients are also provided the option to either accept or decline either delivery or mail-in to keep the list for unnecessary outreach and outreach about a potential action plan. The overall theme is patient centric, which has improved the patient's adherence while maintaining trust and safety of all parties related [4].

The data fields and schema to process and store the accepted opportunity feed are structured in the Optum Rx Sync environment so that identifiable and actionable data can be stored to allow for processed appropriately and tracked as opportunity. Identifying metafor 개 and elements of types of, opportunity, patient, and pharmacy are unique characteristics of the schema. The schema of the Rx Sync was designed to build consistency in identification while processing lines of data for actionable items, while always likely record is fitted to indicate suppression in opportunity for assumption of redundancy (retained to honor opt-out). Timestamping other data fields for created and updated time, and capturing additional data fields of medication and the corresponding billing code for consideration and review. The overall schema structure of the Rx Sync is set up to support monitoring to allow pharmacies to quickly take supported

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action when available to them, while ensuring safe transmission of the data integration and whole supports healthcare environment that fits to enterprise data management and associated analytics [5].

II. RELATED WORK

OptumRx's synchronization initiatives, as noted in "The OptumRx Value Story" [6], shows significant improvements in medication adherence; adherence rates were 30% higher for 80 synchronization customers and 60-day readmissions were down by 33% for oncology and transplant populations. The additional white paper also supplied evidence to support the use of a data-driven innovative model for pharmacy care through analysis and case studies. Optum Labs has utilized its robust data warehouse to conduct useful research to share with the pharmacy field, including presentations at global conferences, around data integration and medication adherence. Peer-reviewed research on medication synchronization programs [7], including the OptumRx Sync program, have reported favorable outcomes for chronic disease and medication adherence. The synchronized care management model appears to have a positive impact on other costs, patient engagement, and health outcomes (e.g., reductions in opioid prescribing and hospital admissions), as referenced in various OptumRx and UnitedHealth Group publications in the pharmacy and healthcare fields.

Several of the studies published from OptumRx have focused on several key medications management outcomes: medications adherence and persistence through adherence rates and refills; cost outcomes through reduced hospital readmissions and overall health care costs; clinical outcomes through better disease control, including data on chronic illnesses like diabetes and obesity with substantial weight loss reported in anti-obesity studies; patient experience through satisfaction and engagement rates; and optimization of healthcare systems through reduced prior authorizations and faster access to medications.Monitoring adverse medication events and interactions leads to risk reduction. For example, OptumRx Sync has been shown to increase adherence to medication by 30% and decrease rates of hospital readmission by33%, demonstrating that, through data integration and analytics, OptumRx Sync and other pharmacy care services may decrease total costs and enhance health outcomes [8].

Another study conducted by OptumRx suggests that Medicare users of Optum Home Delivery for 90-day fills adhere to their medication better compared to using retail pharmacies. Increased adherence is related to improved clinical outcomes and decreased hospital admission rates since home delivery results in less medication gaps and improves persistence. Additionally, there is evidence from the medication synchronization programs, such as those presented by OptumRx Sync, that aim to improve chronic medication adherence and persistence over a year observed more adherence and persistence than other engagements. In more internal exploratory studies, home delivery services were shown to significantly enhance adherance measurements that improve engagement, high availability of medication, and increased refills. To summarize, these studies collectively show that OptumRx data-driven approaches to medication synchronization and home delivery improve medication adherence, persistence, and overall clinical and financial outcomes in pharmacy care and chronic disease management [9].

Compared to retail pharmacies, OptumRx home delivery realizes greater profitability in prescription adherence, with observated adherence rates above 90% compared to 70-75% of retail pharmacies with a 30-day supply.When examining 90-day retail fills, adherence is also 20% better with home delivery. Research indicates that home delivery is associated with 27% to 38% fewer non-adherent people with chronic illness, such as diabetes or hypertension, and a 19% to 47% reduction in the chance of not refilling a medication. Home delivery leads to greater clinical outcomes, fewer hospitalizations, and less time between medication gaps and days without a prescription for Medicare patients. Home delivery benefits are a result of more days of supply, financial incentives, and less access barriers. Home delivery through OptumRx is a better method of managing chronic illness and less costly [10].

The OptumRx studies and their initiatives apply various statistical techniques in order to analyze medication adherence outcomes. Descriptive statistics such as, means, standard deviation, or proportions are used to characterize adherence metrics like the Medication Possession Ratio (MPR) and Percentage of Days Covered (PDC). Analysis of Variance (ANOVA) is used to determine significant differences in adherence rates among groups, while chi-square tests are used to test the independence of categorical data, including patient demographics and adherence status. Paired and independent t-tests are used to compare adherence rates either within cohorts and between cohorts. Logistic regression measures adherence as a dichotomous outcome while controlling for covariates such as age and gender and generalized linear models are applied to adherence related healthcare use, and cost outcomes. Repeated measures ANOVA and post hoc tests are used to evaluate variability of adherence either through time or testing model differences. Sensitivity

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analysis and stratification allowed us to test the robustness of adherence estimates when adjusting cohort definitions and measurement weeks. The use of varied techniques allowed for comprehensive comparisons of adherence while accounting for confounding variables and through different evaluation methods. Logistic regression was the predominant statistical model in the studies by OptumRx while measuring the odds of adherence to home delivery modalities, and also all reported statistically significant differences in adherence outcomes by pharmacy channels as illustrated in Table 1 below [11]:

Statistical Method	Description	Use Case in OptumRx Research
Descriptive Statistics	Means, standard deviations, proportions to summarize adherence measures (PDC, MPR)	Summarizing adherence rates and patterns
Analysis of Variance (ANOVA)	Tests differences between groups in adherence rates	Comparing adherence between home delivery and retail pharmacies
Chi-square Test	Tests for independence in categorical variables	Assessing associations between adherence and demographics
T-tests (paired, independent)	Comparing mean adherence percentages within or between cohorts	Evaluating adherence changes or group comparisons
Logistic Regression	Models binary adherence outcome adjusting for confounders	Estimating odds of adherence with home delivery vs retail
Multivariable Regression	Models adherence impact on utilization and cost considering multiple factors	Linking adherence to healthcare outcomes and cost savings
Repeated Measures ANOVA	Analyzes adherence variation over time or across measurement methods	Longitudinal adherence assessments
Sensitivity/Stratification	Testing robustness across cohorts and definitions	Validating adherence results under different conditions

Table 1: Statistical Methods used to Compare Medication Adherence Outcomes

III. SYSTEM ARCHITECTURE

The OptumRx Sync system design intends to accomplish key business objectives that focus on prescription adherence, patient convenience and savings, operational savings, and overall business efficiency. The system is created to ingest significant amounts of pharmaceutical and claims data from both internal and external sources and consolidate them into a unified data lake and analytics environment. This includes the ingestion of data from multiple internal pharmaceutical management systems, charge codes, insurance subscriber lists, external Rx data streams, and historical claims datasets. Ingesting the data can be done via unique pipelines that processes different data formats with out the need to code for change at the pharmaceutical endpoints with the raw ingested data flowing to data lakes. Data can be aggregated though batch processing tools, added to custom adapters, or api based data collection to accumulate data. Data can be transformed and processed for hygiene with the use of tools like hive, pig, and Talend, for example, turning unstructured datasets into a standardized PDS and optimizing for store in ORC format.

Master Data Management (MDM) and crosswalk procedures are implemented using pig and hive scripts to link patients to insurance holders and aggregate prescription records, generating patient and medication-focused dataframes for models that represent individualized models. The predictive models and ML are built off of the processed datasets to elucidate the opportunities specific to the patient. A feedback loop is created to update the Sync system with accepted opportunities from the Rx online platform. Performance improvements are found in the form of purpose-built datasets, personalized map-reduce tasks, and optimized hive searches that are run on a distributed compute-enabled Hadoop clusters that improve processing exhaustive computation speed and efficiency. Continuous tuning done in parallel with DevOps improve throughput and/or cost status. The system has far-reaching benefits for businesses, increase drug adherence and reduction of patient burden and savings that can be estimated in hundreds thousands of dollars in savings

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related to operational costs with adequate performance reviews. Challenge exists with data silos and performance issues merging large datasets hence developing an ingesting framework or focused PDS with ORC format; utilizing custom map-reduce schema for expediency shown in below Figure 1:

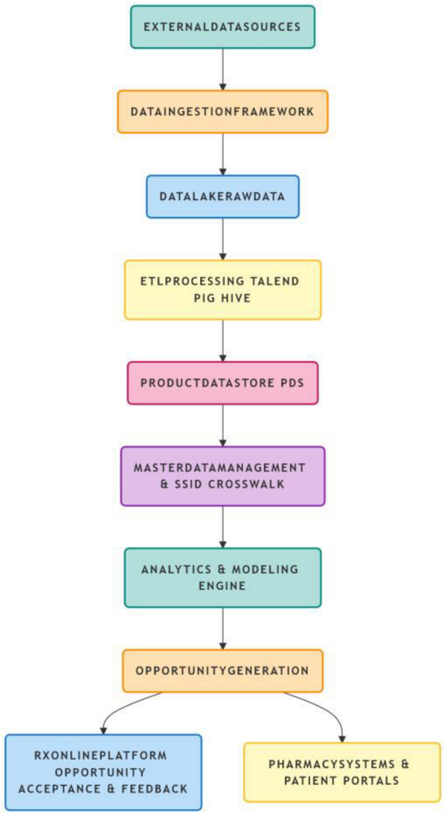

Figure 1: Distributed Hadoop Cluster & DevOps Support

1. **Layer of External Data Sources:**
- Brings together a variety of data sources including pharmacy management systems, claims data, drug master databases, and billing systems.
- Connects patient and pharmacy data using crosswalks and historical datasets.
- Presents raw (non-standardized) data giving a holistic view of medications and claims data.
2. **Framework Layer for Data Ingestion:**
- Provides a scalable ingestion framework with specific adapters for a variety of data formats.
- Supports incremental data feeds and batch loads without affecting source pharmacies.
- Enhances data reliability with retry logic on temporary failures.
3. **Layer of Raw Data Storage and Data Lake:**
- Holds raw data in original format for historical purposes.
- Acts as the single source of truth for all datasets for scalability and future auditing.
4. **Layer of Data Processing and Hygiene:**
- Verifies data formats and consistency using ETL pipelines.
- Normalizes data into a single schema (Product Data Store) and optimizes storage formats.
- Cleanses and enriches data to enable reliable analytical results.
5. **Master Data Management & Crosswalk Layer:**
- Unifies patient and pharmacy identities using SSID Crosswalk algorithms.
- Creates cohesive patient profiles that connect insurance, prescriptions, and pharmacy events.
- Supports analytics ensuring data is consistent and reduces time data is duplicated in the analysis.

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6. **Layer of Analytics and Opportunity Modeling:**
- Processes unified data into insights that can potentially be acted on using machine learning or rule-based models.
- Identifies pharmaceutical opportunities and ranks those opportunities by health and financial opportunities to be had.
- Modifies any models dynamically based on responses received.
7. **Opportunity Feedback & Operational Integration Layer:**
- Enables executed opportunities through a closed-loop workflow.
- Gathers feedback and presents patient opt-in and opt-out capabilities.
- Supports real-time integration for patient engagement and operational efficiency.
8. **Layer of Infrastructure and Performance Optimization:**
- Distributed Hadoop clusters allow for parallel data analysis and scaling.
- ORC storage, as well as other optimized queries, can improve performance.
- Working with DevOps will ensure resources are allocated properly and willing the resiliency of the system will ensure operational effectiveness.

The necessary interfaces and APIs and for the multi-layered architecture of a data architecture. Highlighting the need for connectors / adapters to connect to outside sources of information (e.g. REST APIs from pharmacy systems, insurance lists, API from Claims, etc) . The Data Ingestion Framework Layer requires APIs to upload and download bulk data and REST endpoints for data ingestion from lakes. Cloud object storage APIs such as HDFS REST APIs, S3 APIs or other APIs suggested. The Data Processing and Hygiene Layer interact with query interfaces and other ETL APIs that can include either API-triggered scripts or JDBC / REST interfaces across the data processing. The Crosswalk Layer suggested design a data layer of opportunity modeling and analytics through microservices and REST APIs to be accessed for patient/entity pairing, REST/API endpoints to deploy models, web APIs for feedback intake and acknowledgement of decision acceptance and to close the loop. User interfaces induced operation systems will use REST APIs to connect doctor/patient interactions and pharma.

The infrastructure and performance layer APIs will expose collection and monitoring of ecosystem components of the ODS to include performance dashboards Kubernetes API endpoints, and other such APIs automating both processing, monitoring and management of systems.The following API calls are examples of functional capabilities, outlining key areas of data ingestion, linking patients, executing models, submitting opportunities, and updating status of feedback. A layered API inventory of a healthcare Product Data Store (PDS) architecture provides some nuances of different APIs and their intended use in the architecture for each API layer. The Layer of External Sources of Information consists of ingestion APIs and data source connectors represented, namely pharmacy claims APIs and FHIR REST APIs. The Data Ingestion layer has multiple data ingestion APIs allowing for streaming and batch uploads. The Layer of Raw Storage & Data Lake has APIs allows the ingestion of raw data into data storage options, namely Azure Blob and HDFS.

The Data Processing & Hygiene layer engages ETL orchestration APIs. The Crosswalks & Master Data Management Layer has linking patient identity and matching services APIs included here, while the Opportunity Modeling & Analytics layer engages APIs to serve the model. The Responses and Communication Layer includes APIs to respond appropriately to the patient and engage in communication. The User Interaction APIs are found through the patient and pharmacy portals. The DevOps layer encompasses tools, APIs, and data reports to manage the infrastructure and monitoring APIs. Examples from API areas include standardized APIs for exchange of clinical data, batch upload APIs, APIs especially to uniquely identify the patient, APIs for scoring the model, APIs to accept the opportunity, and APIs for monitoring systems health. As indicated, these APIs have both interoperability and scalability roles affecting decision-making which directly impacts patient care and can be safely amassed through the integrated standardization among systems.

The healthcare-centric Product Data Store (PDS) architecture outlines multiple layers of responsibility so that each layer retains restricted authority. The Layer of External Sources of Information identifies its connection to numerous sources of unprocessed data from varied modalities. The Data Ingestion Framework Layer is responsible for the transportation of the data, as well as maintaining its original look and feel, and moving the data into a data lake. The Data Lake & Raw Storage Layer safely hold this raw data, commits to tracking versions of data, and serves as a source repository of a single version of truth. The Data Processing & Hygiene Layer standardizes and cleanses the data in preparation of occurrence for queries and ETL workflows from the lake. The Crosswalk Layer and Master Data

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Management identify different identity types, eliminate duplicate data, and cross-analyze data. The Opportunity Feedback & Operational Integration Layer accounts for specific processing practices that facilitate patient portal requirements. The Layer of User Interaction Interfaces provides users a secure and participative engagement with opportunities. Finally, the Infrastructure & Performance Layer manages resource functionality and optimization in various capacity sizes. In summary, this architecture defines the specific responsibilities of layers to allow for safe data-driven patient care.

Key performance indicators that will be relevant to a healthcare Product Data Store (PDS) architecture, like OptumRx Sync, will be organized in two ways: the technical and business results. The important measurements are latency of data ingestion (i.e., how long does it take to absorb and store external information), data pipeline throughput (i.e., how much data was processed during a period), and data quality data (i.e., the percentage of information successful in passing validations). ETL job runtime and success percentage measure how well the transformations are working.When considering storage and queries, query response times provide an indication of data retrieval speed, while a compressed format defines efficiency. The latency of model predictions provides the speed of deriving insights, and model performance measures precision and accuracy of identified opportunities. The cycle time of feedback is a method of measuring the time lapse from acceptance of opportunity to the opportunity being instantiated in the PDS system.

Operational efficiency is indicated by the number of prescriptions processed and also calculating reduction in operational costs, which may include savings from generic drug utilization. Patient outcomes incorporate metrics indicating improvements in medication adherence, reductions in opioid prescriptions, patient satisfaction scores and reductions in rates of hospital readmissions due to medication synchronization. Metrics related to infrastructure typically focus on monitoring resource usage, failure rates in jobs, and system availability, indicating that the data processing and analytics can be reliably processed. Performance measures assist in regular monitoring, while can ultimately improve outcomes and potentially reduce costs in terms of healthcare.

In evaluating the performance indicators of a healthcare PDS system, such as OptumRx Sync, there are several datasets that are determining factors. They include prescription data and patient specific data, such as demographics, adherence data, and prescription history. Billing data or claims data on insurance claims, and insurance claim acceptance or processing history can also indicate information on operational efficiency and decrease costs. Operational data from pharmacy workflows, such as timestamps of synchronizations and logs of workload can suggest an efficiency and workflow-based metrics. Clinical data and health outcome data, such as readmission data and adherence metrics can empirically demonstrate connections between patient adherence and health outcomes.

Patient satisfaction data, such as CAHPS scores or Press Ganey Ratings, would also have importance in evaluating engagement and centers of satisfaction. System logs and infrastructure logs will also be able to provide the metrics for evaluation of uptime and failure of tasks. Reviews of the system and infrastructure logs should be able to provide scalable metrics for performance. Collectively, these datasets provide empirical inputs for monitoring and evaluating clinical, operational, financial and technological performance aspects of the PDS architecture to better undergo future monitoring. While data from real population settings is required in order to measure outcomes in the producing setting, synthetic data or anonymized data sets are often utilized at times of development or testing in a more simulated approach that is depicted below in Figure 2:

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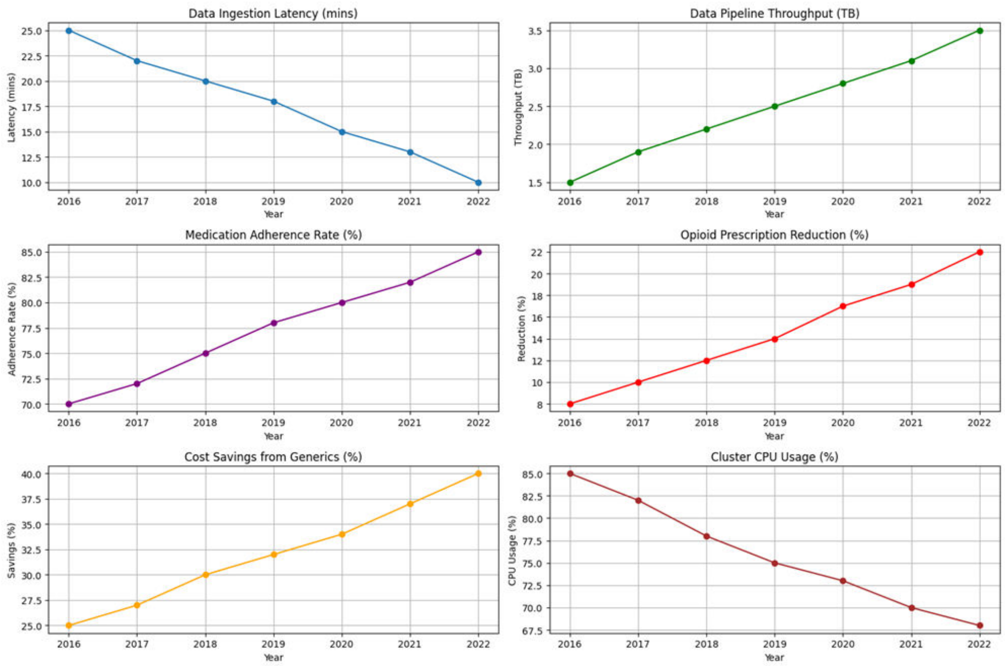

Figure 2: Key Healthcare PDS Performance Metrics

IV. CONCLUSION

The Rx Sync project illustrates usage of a Product Data Store (PDS) architecture to improve pharmacy operation, reduce healthcare costs overall and improve medication adherence through integrated data and analytics capabilities. It offers personalization options for patients such as refill synchronization and substitution of generics, yielding a return on investment (ROI) benefits such as reduced opioid prescriptions and convenience. In this pilot study we assess the scalability of ETL pipelines for distributed computing to resolve issues regarding data silos. The next steps for Rx Sync include enhancing interoperability, integrating pharmacy and health systems data in real-time, and predictive modeling utilizing AI for patient care personalization. The patient care model will leverage decentralized data marketplaces and enhance collaboration with telehealth platforms to provide a more complete patient health information to improve the patient-centeredness and accuracy of healthcare delivery. This article demonstrates that data ecosystems have become necessary enablers of the pharmacy services evolution and enhanced health outcomes.

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