Medical Subsystem for Blood Tests Evaluation Based on E-commerce Solution

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Abstract

Cloud computing, in combination with distributed data aggregation, helps humankind solve the problem of data collection and processing near the source of collection, supporting the possibility of distributed systems processing data in the nearest node and further aggregating the data into bigger sources for normalisation and application of the data models and data statistical processing. Medical data are well known for their exceeding sizes and huge dependencies on specific needs; however, applying contemporary models, combining different subsystems, and applying analytic approaches help resolve serious automation problems. Data aggregation, combined with data processing and visualisation, enables medical business owners to decide how to plan the budget for the upcoming period. The study foresees the usage of data collection, processing, and visualisation of medical test data and the projection of wasted percentages with the feedback loop for service providers integrated with an e-commerce solution. The system composition, lifecycle, and process transitions are developed according to the business requirements of the companies and their sales, returns, waste analysis documents, and corresponding processes. Data-receiving models and transformations are mentioned but not described due to commercial secrets, which do not impact the approach of system development and can be applied to similar or other industries.

Keywords

Processing at Cloud Services, distributed data aggregation, medical subsystems, interoperability

1. Introduction

The current society has many challenges related to the medical and healthcare systems, which constantly change in the context of reform. However, medical servicing systems had a serious hit of activity related to the COVID-19 pandemic [1], which forced people to rethink their concept of interaction with medical institutions completely. With the number of patients exponentially increasing in the pandemic, the healthcare system requested utterly new approaches for logistics and support of medical institutions from the perspective of medical tests, the readiness of staff, and medical equipment to process an increasing number of patients and patients' medical records. At that very moment, the vast majority of medical institutions noticed the urgent need for modernisation of their laboratory bases, and more laboratory networks came forward and served as certified centres of blood sampling and processing for medical institutions. It enabled the organisations to support more patients, enforce consultancy rather than concentrate on laboratory investigations to make expert conclusions on each patient's case, reference the disease's course, and validate the treatment results [2]. The supply chain of such organisations is still based on e-commerce solutions of specific types that can work with enterprise resource planning ERP systems. Besides standard solutions for e-commerce solutions satisfying the requirements of standard users, we see more and more e-commerce applications creating additional subsystems to automate specific fields of solutions where e-commerce is being applied.

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2. Theoretical background

Recent research proves that information and computer technologies (ICT) in healthcare may greatly improve the level of service, support, and maintenance [3]. Some evaluation techniques for effectiveness are measurable, some are subjective, and some can be identified via supplementary parameters, models, and techniques, which contemporary businesses must invent to keep the usability and parameter collection as simple as possible.

The effectiveness of the healthcare system ensures human rights to healthcare and satisfies such a need. It is essential to investigate how we can develop a subsystem that incorporates contemporary technological advantages to optimise the process of evaluation, approximation, and identification of supplied material volumes for upcoming periods.

Among the advantages is substantial research on applying cloud computing to process calculations and evaluations at specific nodes, which has been effectively applied in different industries[4]. E-commerce reacted immediately, transitioning the application's most significant data and process-loaded segments to the cloud computing nodes or edge computing by transferring the solution to cloud services and implementing additional services.

Data aggregation, with the application of cloud computing possibilities [5], allows the process of distributing data and visualising them with contemporary reports and enables all that to the medical networks to perform ordering, logistics, inventory update, waste registration, and forecasting, a real benefit of an automated system for international companies, mitigating the risks of insufficient tests, liquids, and supplies. That is why different medical institutions have switched to automated devices, which can lower the expenditure of different liquids and avoid overdosing. At the same time, such devices can collect statistics on used liquids or supplies that can be exported to external networks, which may be helpful for automated aggregated systems.

The timely availability of products guarantees uninterrupted work of blood withdrawal centres, blood test laboratories, and many other institutions taking samples, including reproduction centres and sometimes even home medical visits, which are necessary if the patient has limited movement activities, etc.

It is a hot topic if research is accelerated with the constantly increasing number of tests the person needs to perform to start the diagnostics. Just six years ago, the number of tests was dramatically low, and COVID and blood tests exploded the industry of medical supplies for various tests and applications. Even though the number of tests increased, the supplier's physical aspects did not change seriously; however, the medical devices for processing increased significantly.

The vast majority of medical laboratories are creating supply chains based on pharmaceutical companies and agencies that correspond to medical and local standards and can satisfy diligent logistics and sales agreements. E-commerce solutions can do many activities as they may have a network or distributed architecture and involve Cloud Technologies internally. Some of the elements of cloud solutions are logistic elements, which are part of almost every E-commerce solution. One of the arguments to apply and support the logistics idea of using alternative logistics routes may still support medical laboratories even with higher delivery requirements, including satisfaction of cooling and heating delivery requirements [6]. Regardless of payment and delivery constraints, the prominent role of the evaluation is to predict how many supplies should be purchased shortly and in the context of an upcoming year.

To analyse and build the contemporary subsystem aiming to support medical blood tests and international organisations with contemporary devices, it is suggested that the international companies' current operation activities and infrastructure ordering from the integrated e-commerce solutions be analysed. A complete set of business analysis tasks will be formed as separate work; however, the fundamental solutions suggested will be based on network analysis [7] applied to the solution domain. It will enable the analysis of two scenarios when a higher or lower level of automation is applied. Indeed, the data gathered from the equipment reduces manual entries and creates data slices for analytic reports. Some laboratories still prefer manual updates since only some of the complete set of equipment can be installed to automate the work entirely. Thus, manual solutions should still be supported. However, both approaches are aimed at validating the possibility of collecting a minimal set of parameters included in an automated framework assisting medical organisations with a closed cycle of ordering, analysis of remaining items available, analysis of wastes, and informing the provider of possible waste percentages, which forms the set of tasks for the current paper.

Analysis of the current lifecycle with elements of cloud computing and data pre-processing with possible aggregation can be supported with edge computing as a model that optimises the cloud computing system by processing data closer to the region where it is collected and used, a kind of cloud instance [8].

The cloud computing primary edge computing definitions certainly include the type of IoT data retrieval from devices and sensors that provide aggregation and processing. However, computing and calculations can be enriching factors that may go hand-in-hand with the decentralisation of functions and may seriously decrease data latency [9]. Geographically distributed applications, like in the case of international companies [11], have many similarities with the edge network of source data and may easily cover the essential capabilities such as application, computing, networking, storage, and performing processing services satisfying the agility requirements. In our case, real-time business connection and data optimisation are the prominent factors for minimising possible development costs.

Cloud computing has a decentralised architecture; it empowers several features that can be quite effective, such as processing data closer to the user's recipient region or location [11] and interacting with allocated data, which is primarily gathered if IoT devices generate it. In combination with cloud services, this data can be aggregated and transferred to generalisation units, satisfying lower latency and acceptable computation power. These features are mission-critical in healthcare [12] and organisation and institution management [13].

Thus, in our case, we may consider an international company with branches in different countries in Northern and Latin America, Europe, Asia, and the Pacific region that validates how to satisfy the needs of specific branches or the needs of the whole company in a specific region with aggregation to the corporation in general.

To make this happen, the existing e-commerce system infrastructure should be extended with a subsystem that can regionally collect, process, aggregate, compute, and transfer data to the upper level.

Thus, the data collection problem, addressed by the decentralised database and aggregated per layer and its usage via service, delivering data to the users' computers to solve obscure or localised issues, is already solved with distributed systems. Therefore, the data for particular medical meta-data will be stored in the respective subsystem. The system layers should consider local and global levels to guarantee granularity.

Hence, the research aims to illuminate the suggested approach and highlight the main aspects and results of medical subsystem development and usage.

3. Methods

The comparative analysis of e-commerce systems is skipped here since we focus on e-commerce, which is based on ERP systems that simplify the logic and data processing. The module of industry-specific adaptation for data collection, processing, and additional functionalities added to the E-Commerce solution as an extension is provided and considered. As the current trend of many e-commerce systems is SaaS solutions, that part is also considered. It increases the coverage of use cases and the breadth of applications.

To focus mainly on additional components and go in-depth about applying the extended functionality, doing calculations, and aggregations, we consider that the e-commerce solution already uses cloud solutions, integrates cloud ERPs, and works with cloud web shops.

The solution should consider presenting reports that reflect the data and results of the model application (forecasting), which is crucial for decision-making for all four key process players. They need it mainly to keep the process transparent and effective. The solution should suggest both the automated one, where IoT elements will provide the data collected, and the manual one, which allows the end-user to enter the data for further model adjustment.

Use-case diagrams and application diagrams, along with screenshots of proposed solutions, will allow us to dive into the heart of the development process and the main concepts and solutions proposed. Models applied for forecasting are still part of the commercial NDA-protected signature, so they are not highlighted, as they are not the core part of the provided results. For the reader's audience, the current prediction model takes the annual amount of purchased items in the year's projection, considering the already purchased items and the average monthly volumes purchased in the recent three years. This means that purchase volume should be at least the average of a specific month for the last three years. For each upcoming month, the trajectory is built based on the recently purchased amount in the upcoming period so as not to be lower than the average of an annual total per specific item. The math is relatively simple for implementation and will not slow down the Power BI report.

4. Results

The medical subsystem is designed to support users' roles with actual real-time report information and updated visualisation of data on supplies needed for the upcoming period. As part of an integrated e-commerce solution, a subsystem enriches additional elements, resulting in data queries fed to reports assembled based on collected data (Figure 1).

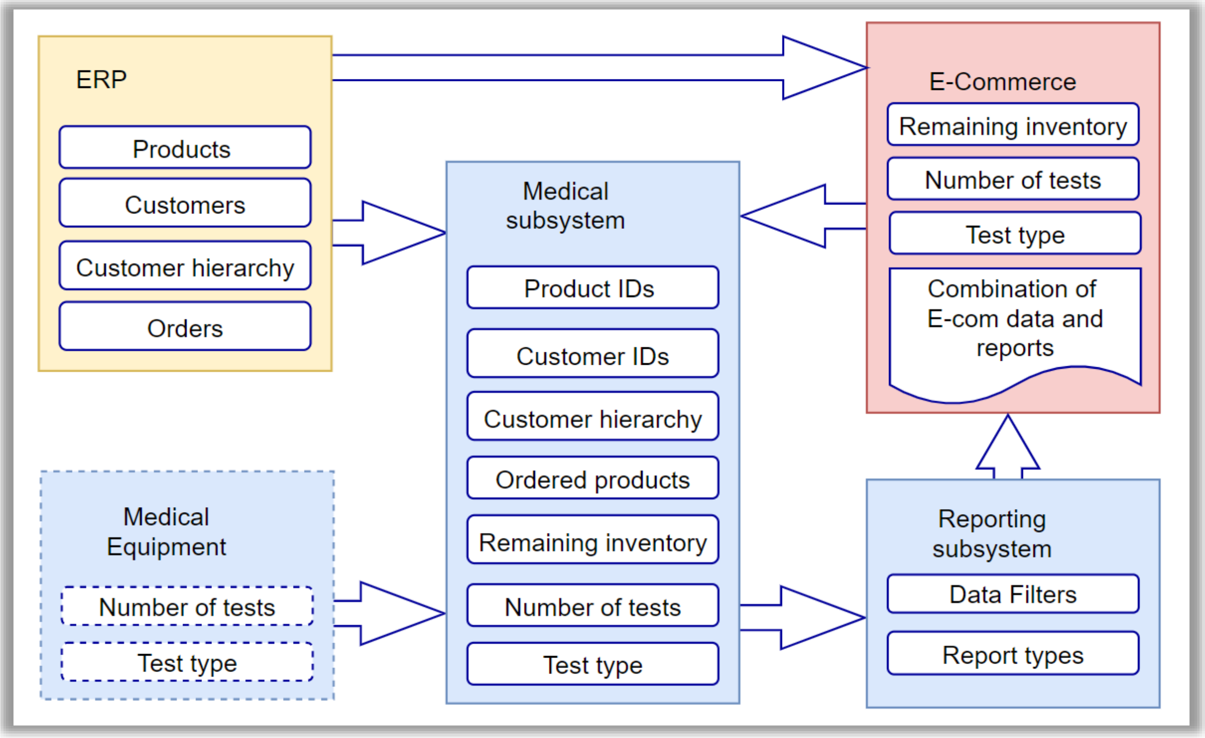

Figure 1: Data exchange model

Let us review the data schema for the proposed system and analyse the data flow in the context of the applicability of the cloud services and data layers for different roles.

The medical subsystem is sufficient to support medical institutions with up to 4 levels of hierarchy to support reporting. The number of levels may vary and impact the number of aggregation layers, which the supplier may outline if they can support such a hierarchy level. Most ERP-based e-commerce solutions support four levels. However, such systems may still install extensions, enabling more options. Reflection at the hierarchy level may impact the number of layers for data aggregation and the number of potential customers to be added to the system.

4.1. Architectural solution for the system

The general structure of the system proposed will be based on an ERP (for example, the SAP Hana Cloud) integrated with an e-commerce solution, as presented in Figure 2. Cloud **ERP** will ensure that every region accesses the data with minimal latency and consider data delivery to another subsystem.

The **proposed e-commerce** services will be based on cloud services that may guarantee presence in specific regions and data layers on the local level. Two servicing APIs, marked in blue, will be provided for the front-end and back-end to control the usual e-commerce solution functions and the servicing functions of exporting necessary anonymised data to the medical subsystem.

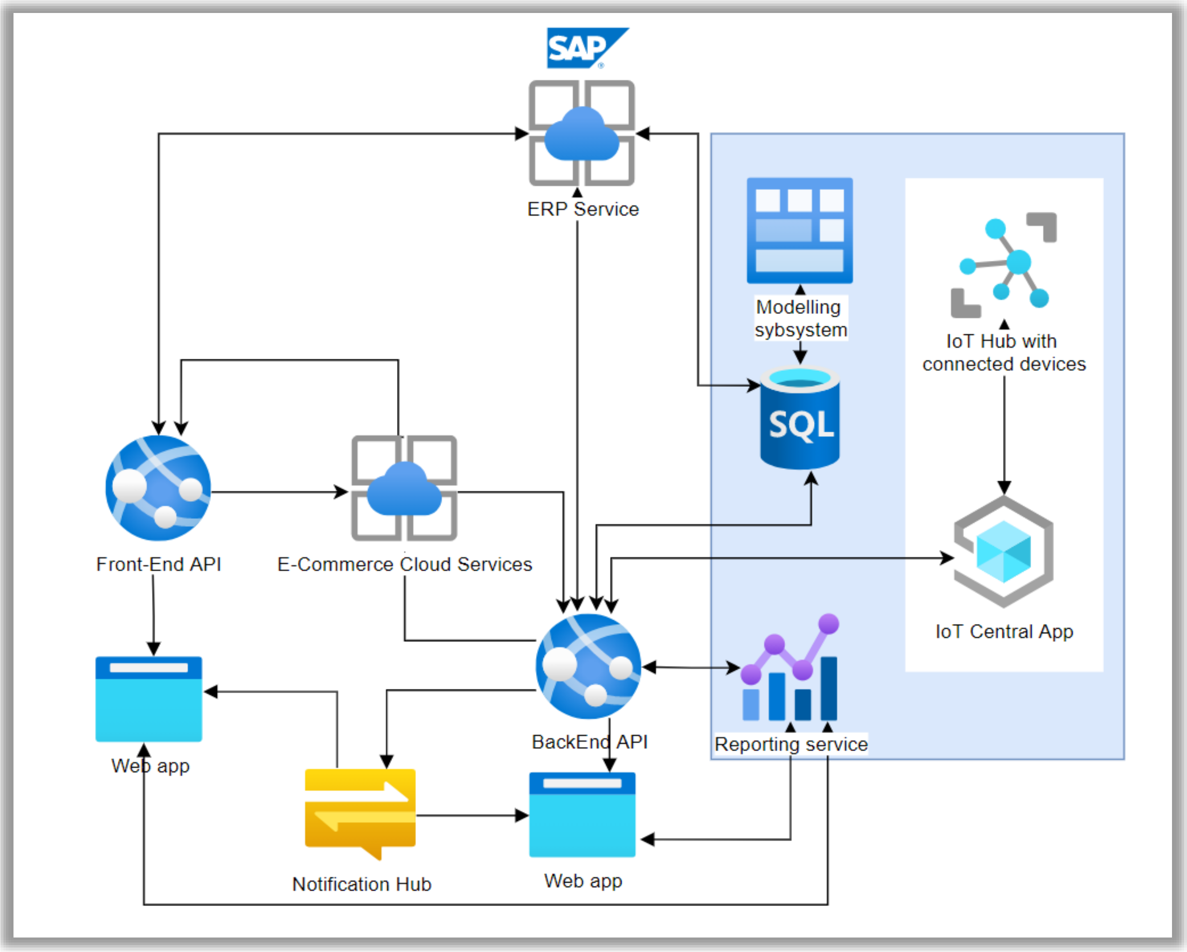

Figure 2: Architecture of the integration of the API with applications and services

Both APIs should have a respective control by Web application that brings ease in access allocation and control. Both applications will serve as entry points for groups of users, where the front-end and back-end users will have their levels of access and customer-type recognition. All the above units support node allocation and transfer of permissions to specific nodes of the allocated service the user works with.

Data collected from the nodes will be processed within the service call and stored in the medical subsystem node, which has storage and access to other aggregation layers. It will ensure that users will operate within their data layers and use the calculation power of the specific node.

The medical subsystem will have servicing functions to interact with reporting services and IoT devices and collect data from respective devices.

The reporting service will have a monitoring subunit that interacts with the system's back-end API to signal which report still needs to be updated. Such triggered notification requests will be made at the customer level. Aggregated data will trigger signals to the API to inform the managers, who should act and enforce their subordinate employees to provide reports regularly for correct data aggregation.

It is worth noting that the IoT may not be added to every organisation, which is why the e-commerce solution will still send the data via the e-commerce cloud service to the medical subsystem to store the data and feed it to the modelling subsystem, which is responsible for making analysis and predictive reports for the upcoming period.

4.2. Data transfer between the parts of the system

As long as the customer and product data will be stored in the ERP and the main focus of the customer, manager, administrator, and supplier will be interacting with the e-commerce solution, it is suggested to develop and implement the solution architecture and describe the use-cases for the medical subsystem that will be serving as the data storage, aggregation unit, and model application unit that will work for the local nodes as well as for the upper aggregated level for global statistics.

Review the data structure needed to develop the overall system data flow.

The **ERP** will provide a list of "product IDs" and "orders" that were explicitly purchased, along with the customer ID, "customer hierarchy position," and "customer type."

The above attributes are needed for proper reporting filtering and layer distribution for proper aggregation happening in the medical subsystem and have a projection to the reporting system. The customer data will be anonymised to satisfy the requirements of PCI compliance, which is a vital requirement for the General Data Protection Regulation according to Regulation (EU) 2016/679. Thus, the medical subsystem will work with the data only around specific customer IDs, which are fully anonymised and will solely use customer-respective attributes for reporting.

There is a specific medical equipment subunit of the system that has IoT sensors that may collect data and avoid manual entry of the number of tests performed and gathered: "Test registration number" reflects the total quantity of tests in a specific time range; "Test type" characterises the substances and supplies needed for this type of test.

The **Medical Equipment** sub-unit is a variable part that will support the data aggregation from the automated services. This is quite a novel part, reflecting this part of the solution. However, the medical laboratories still do not guarantee a similar unified type of equipment.

The reporting subsystem will differ slightly from the general medical system, as it may operate across the database and reflect pretty much any report supporting technological aspects.

The e-commerce part will enable the respective role to send the remaining inventory to the medical subsystem, ensuring the model is supported with proper data. If the Medical Equipment sub-unit is unavailable, the number of tests with respective test types will be manually entered from the e-commerce system.

Rendered reports will reflect the combination of medical subsystem data via the reporting subsystem unit, applying the report type and data filters to the data and accessibility layer and reading either the specific node data or the aggregated territory layer.

Indeed, the current version is an initial implementation that can be extended and updated; however, for the moment of research and implementation, it has already provided quite good results with the current setup.

The essential operations of the platform are based on the primary existing nodes, which will be integrated with new subunits following their requirements and data integrity to help the layers function, respectively.

4.3. Usability case

The current solution's foreseen use cases satisfy all 4 groups of roles using the system indicated in the use case diagram with the main actors of the process, Figure 3.

The leading role enables customers to maximise profit while maintaining reasonable supply satisfaction and uninterrupted service. The system provides notification services regularly, enforcing the data entries in due time. An automated service for collecting the test results avoids requiring the customer to enter the number of tests in automated or semi-automated mode.

The primary users of the subsystem are medical analysts (customers) and their senior managers (managers) who are observing state-of-the-art (receiving notifications about reports not submitted or updated, entry/checking of the inventory values), organisation administrators (review dashboards, adjustment of the reporting filters, validation of the data integrity), and industry representatives (review dashboards, purchased volumes, and projected orders in the upcoming future).

Indeed, the current diagram only focuses on the medical subsystem and excludes all e-commerce functionalities and supportive use cases that are covered by default ERP or cloud services. It must fully disclose the main point of embedding the multilevel possibilities for users to access the reports from the respective data layer.

Nonetheless, the diagram already indicates that two levels of users, customer and manager, may see different reports and get access to several layers of data produced for reports by different layers of aggregation. Customer operates with reporting only within their account, which is local, and using the locally aggregated data fed to the reporting system, where the manager may act as a customer and be able to switch to the level of customers observing, which will switch to a different aggregation level and feed the report with respective data. As the implementation is done within the real-time system, accessing the real-time e-commerce and ERP data will refresh the enrichment of the report.

A similar situation happens to the administrator, who may switch between different levels of aggregated data since the data validation and integrity check, customer hierarchy validation, and transformation still access different data sets and involve different system nodes.

From the supplier's perspective, no granularity of different layers of users is foreseen, only the corporate level with aggregated data, since the supplier is more interested in branch, geographical, and corporate levels rather than customer-specific.

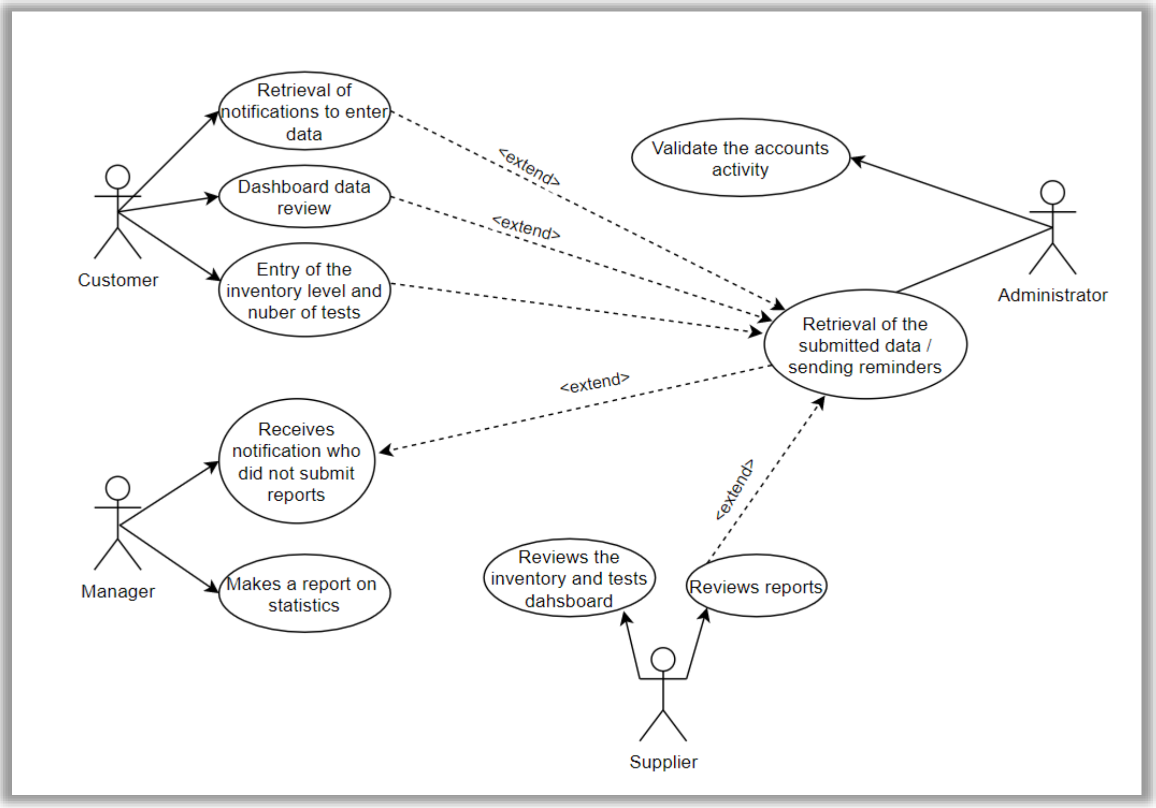

Figure 3: Use-case diagram with the main actors of the process

Therefore, the process goes further: providers submit the data, which is then validated by the system and other customer hierarchy levels involved. To keep the data up-to-date, the key players receive notifications on missing reports or overdue deadlines for report submission. Dashboards are accessible for crucial process players, supporting the overview process daily.

Every e-commerce solution already contains the full features and activities that satisfy the customers' need to find the product. However, the place where reporting is to be embedded should correspond to the requirements of minimal latency and keeping the requests to the real-time processing units at a minimum. Thus, the long lists and search results should be free from unnecessary calls.

Thus, the central reporting places of the e-commerce landscape should be the product detail pages, as they are not using batch processing models, where lists and comparison pages will have a more significant number of requests to the medical subsystem. Embedded reports will be shown via a direct API call that renders the report on the page. This can be achieved in various ways; however, the report must read the aggregated data from the medical subsystem so that the data is reflected.

The usual start of an analytic report will be triggered by the button Analytic Report, which will start a request to report and send requested parameters, including the report time. So, the page is updated with specific segments reflecting data; see Figure 4. The initial load should not trigger a report since there is no need to bother the additional subsystem if the customer is just willing to read the product details.

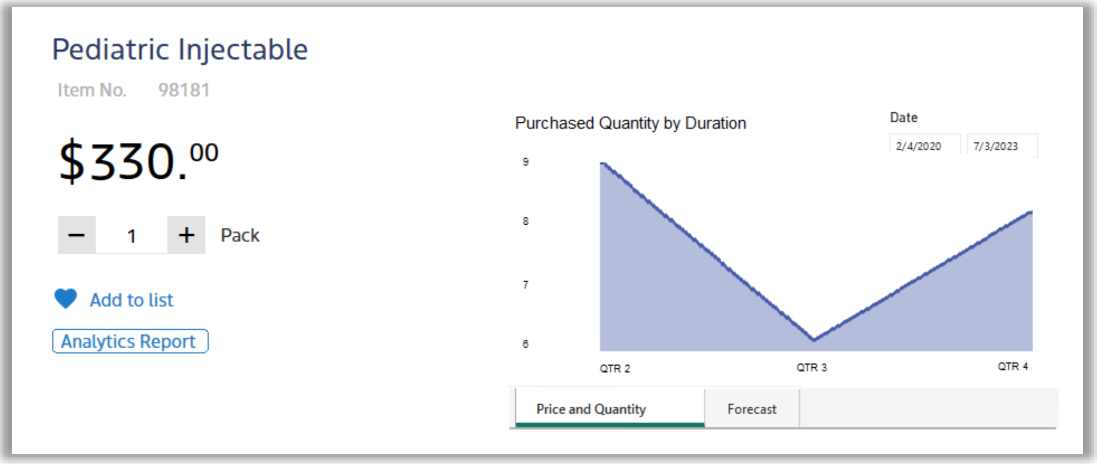

Figure 4: Example of report rendered on the E-Commerce page with the price diagram

The customer should be able to choose between report types directly on the same page without reloading the page and minimising the impact on the current page load time, which is crucial for e-commerce users.

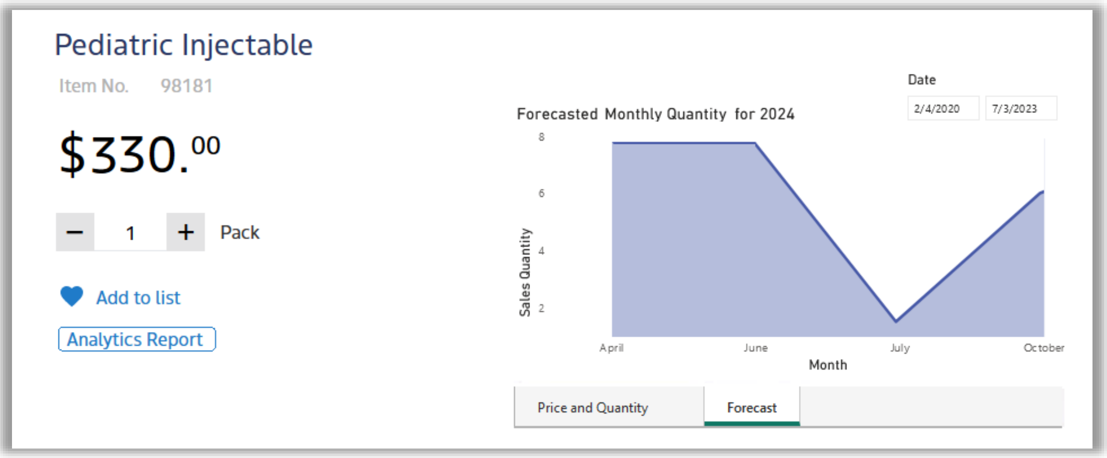

Figure 5: Example of report rendered on the webshop page with the prediction model results

Similar solutions for multiple ordered products can be embedded in the customer's "My Account" section, where the aggregated data for the most purchased products may be displayed to the customer and the manager.

Similar reports may be accessible to the supplier in a product or customer context.

5. Discussion

The solution architecture is structured to support distributed nodes and their coverage with network and cloud solutions. Data structures and solutions are relevant to representing taxonomies in the CIT polyhedron system [15].

Implementing a medical subsystem seriously extends the solution's applicability in general and extends the current integrated solution with subject-domain data compared to the existing standard e-commerce system. Collected data processed in the cloud services demonstrated good results from a latency perspective; however, it may need more extensive validation in other cases.

The infrastructure and data sets are arranged according to European integration and the main principles of findability, accessibility, interoperability, and reusability (FAIR). International standards require software developers to respect the European Union declaration of open data and usage in the medical and governmental sector regulated by Directive (EU) 2019/1024, which is crucial to obey the law and ensure data protection according to GDPR (General Data Protection Regulation according to Regulation (EU)) 2016/679 and Guidelines (EU) 2020/C 122 I/01.

The system functions based on different add-ons implemented as extensions that connect via APIs and services, supporting cloud technologies that enable horizontal scaling.

From the usability and applicability standpoint, the coverage of 4 roles of users, including two types of customers, corporate analysts and corporate managers, opens the broader analytical possibilities for the plans of ordering versus reporting of the tests performed. Administrative personnel support ensures the integrity and validation of the aggregated values on the level of operation within the e-commerce platform—the potential extension of the API calls for exporting more raw data for further adjustments. The accessibility of the supplier and the extension of their visibility of purchased volumes and data modelling for future periods makes it possible to project production volumes. As described in [14], the stakeholder's data should respect sufficient precision and have a layered structure.

Transparency plays a crucial role in e-commerce since the critical indicator of engagement of all stakeholders in the processes may be guaranteed with only available data and thoroughly validated reports. Current publication activity demonstrates the interest and importance of the subject [16], [17], and the whole importance of medical reporting [18], [19] with the application of contemporary technologies [20] in the post-COVID-19 period.

The biggest advantage of the proposed solution model is its scalability for different regions. It can be applied to various types of businesses where generalised operational data is most beneficial. There are many famous solutions for Admin Panel reports related to revenue, operational evaluations, etc. Front-end reports are beneficial for ongoing operation functionality.

Among the application's limitations is that the business-to-consumer (B2C) scenario should be excluded, leaving the power for business-to-business (B2B) scenarios. Power BI reports at the highest license level allow around 480 live connections per second, which may easily be abused by random users from the consumer segment.

From a calculation perspective, the ERP system's calculation power should not be utilised. Several calculations impact the routine operations that are called to serve the daily operations.

Figure 6 below represents the comparative analysis of the period recorded in analytics. Minding that the project went live in August 2023, the number of shop accounts created in the webshop seriously increased, proving usability. In contrast, the new shop account creations indicated spikes around the seasonal exhibitions and fares. The number of page views is stable; however, the number of orders created offline seriously dropped after migration to the newer architecture.

A stable trend of transactions increases with the usability and scalability of specific regions that have a stable reflection of the transaction amount and value of online transactions.

6. Conclusions

The paper proved that the extensibility of e-commerce solutions enables subject-oriented add-ons and components that may play a crucial role in the work processes of medical laboratories and supply organisations. The suggested approach allows for consolidating data and aggregating values to help laboratories make better purchase plans and evaluate supply chains more effectively.

The proposed model enabled many solutions to apply the technologies in combination with the software available to support a broader range of applications. Examples of medical devices indicated how visual and effective a combination of a reporting system with a data processing subsystem is and how the approach of the fully automated solution may be extended with manual entries and still follow all processes of data integration and integrated system functioning daily.

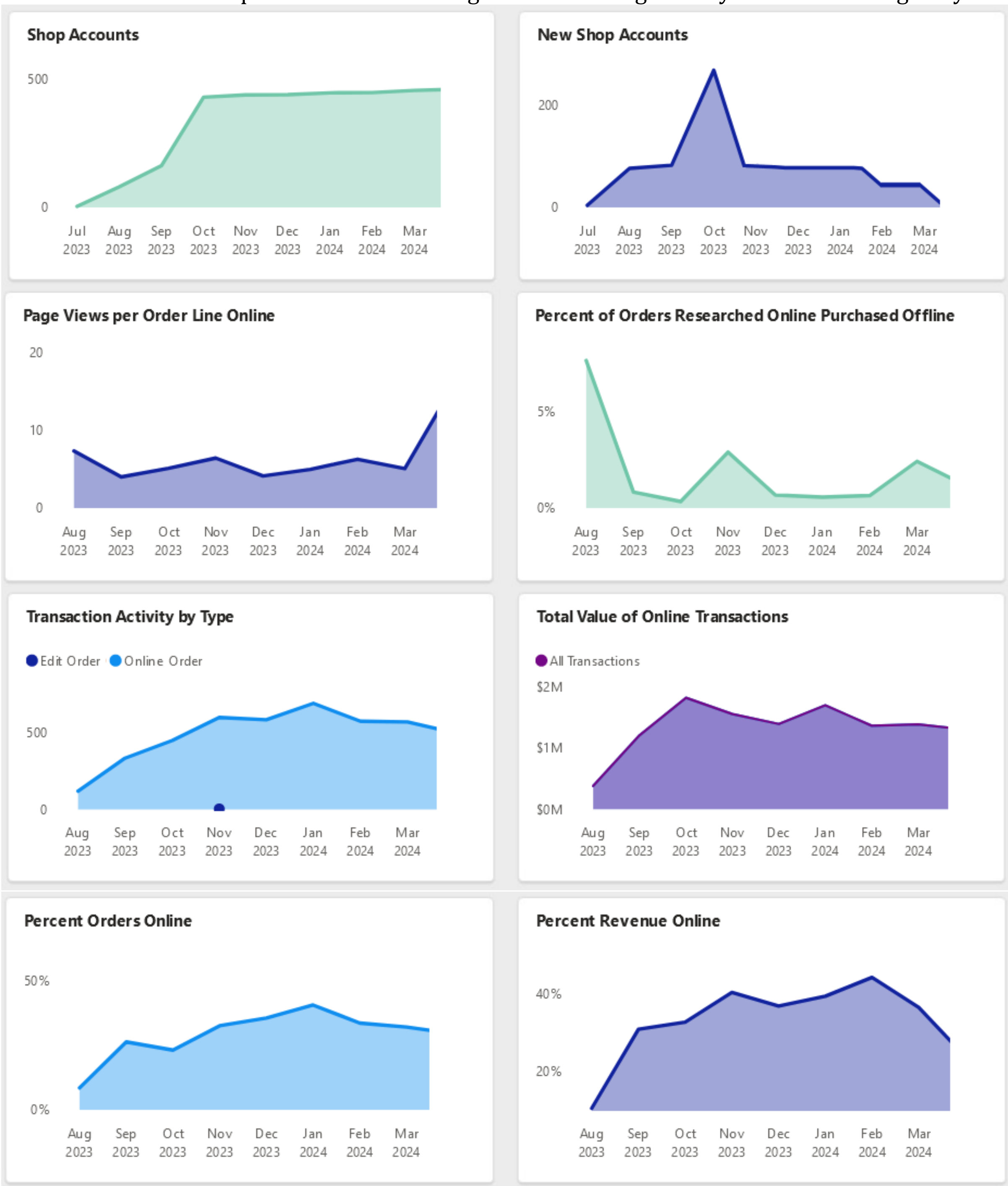

Figure 6: Comparative analysis of the leading critical indicators for the new platform implementation in August 2023 to date

Particular efficiency is found in the local validation segment for organisations and organisation branches since such organisations can represent each department and evaluate their particular level of purchases and potential purchase plan. Aggregating the data at the company level supports faster evaluation and reporting.

A wasted algorithm characterised by the number of tests is an essential part of the validation model and appears as a corrective factor for the solution from the customer angle as well as from the product angle.

Aggregated data at the company level allows the centralised allocation of the data for managers and the reports at different levels of granularity. Cloud computing ensures that the medical subsystem satisfies an acceptable level of productivity and calculation possibilities with minimal latency. Even though the data on the local nodes is calculated and stored, the aggregated data across the regions will have two modes: server-side aggregation, which involves extracting data and building reports on the fly or creating pre-rendered reports for delivery to the end-user.

Adhering to the FAIR principles and the stipulations outlined in Directive (EU) 2019/1024 and Regulation (EU) 2016/679 is crucial in the context of medical information. Taxonomies can serve as a potent method for representing conference data. The digital transformation of medical information can contribute to establishing equitable and transparent conditions. These guidelines follow the Guidelines (EU) 2020/C 122 I/01.

The proposed approach can be applied in different application areas, propagating solutions combining hybrid systems with external services for aggregation visualisation and API integration.

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