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COMPARING SQL AND NOSQL DATABASE PERFORMANCE FOR HANDLING HIGH TRAFFIC IN E-COMMERCE WEB APPLICATIONS

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Abstract: The need for handling a large amount of data, combined with the fast evolution of e-commerce sites, has made it important for databases to work smoothly and at scale. By examining different research and benchmarks, it points out what makes MySQL and PostgreSQL solid relational databases compared to MongoDB and Cassandra as non-relational databases. SQL databases provide reliable results and work well with complex sets of commands. NoSQL databases are better at growing without vertical boundaries, withstanding failures, and being flexible, so they are great for web applications handling a huge amount of traffic. The research also analyzes what specifications are important in e-commerce platforms, features of web applications, and methods that make it possible to see how databases perform when things are changing.

Keywords: Structured Query Language (SQL), Not Only SQL (NoSQL), MongoDB, MySQL, PostgreSQL, E-commerce, High Traffic, Web Applications, Database Performance, Scalability, Big Data, Data Architecture, Horizontal Scaling, Query Optimization.

1 INTRODUCTION

The fast increase in e-commerce has influenced how businesses work and interact with customers, making it important to have effective and flexible data management systems. Since online activities now create a lot of data, selecting a database technology that helps keep the service running smoothly and makes users happy is very important. Among the different database systems, SQL and NoSQL have become the most important and are chosen for particular types of applications due to their features. Usually, SQL databases are used to manage organized data following the relational model that groups records into tables with defined structures [1][2].

In terms of database software, SQL and NoSQL systems are different. A great deal of recent work has compared the features of relational database management systems (RDBMS) like Oracle versus non-relational database management systems (NoSQL) like MongoDB, for shading, consistency, availability, performance, and scaling. From what it can see, SQL databases are more suited to OLTP tasks, while NoSQL databases could be the way to go for big data analytics due to their uniquely structured data [3].

In general, because both relational (SQL) and non-relational (NoSQL) data structures are feasible possibilities, it is desirable to combine them when choosing a database to store information about a system. To pick the best choice, one must consider various distinctions, quote Kaur 2013 Modeling. This article compares and contrasts relational and non-relational database engines, including MySQL and MongoDB, that are both SQL and NoSQL oriented.

Combining relational (SQL) and non-relational (NoSQL) data structures is preferable when selecting a database to store system information, since both are viable options. Picking the right one requires thinking about all the differences, quoting Modelling. This article takes a look at MySQL and MongoDB, two database engines that aren't relational but are SQL and NoSQL-oriented, and looks at how they compare and differ [4].

Online shopping is referred to as e-commerce. The term describes the exchange of goods and services over electronic networks, most notably the internet. The term "e-commerce" refers to the commercial activity that takes place entirely online, using the internet and other associated technologies like EDI [5][6]. Buying and selling goods and services using the Internet is known as electronic commerce (or "e-commerce"). Several different payment options are available on the site, such as digital shopping carts, credit cards, debit cards, and electronic money transfers (EFTs) [7].

There has been a big shift in the way E-Commerce companies operate (provide services, and manage customers) in the past few decades. Mostly, changes happen because of new developments, including Web 3.0, ML, and AI have arrived. These innovations have paved the way for the creation of S-Commerce platforms, which merge aspects of social media with those of electronic commerce. Also, various accessibility technologies have made E-Commerce apps more user-friendly [8][9]. As a result of 5G, mobile commerce has made commerce applications more available, helped increase sales over the internet, and lessened the usual experience of shopping in stores.

2 OVERVIEW OF DATABASE TECHNOLOGIES

Expert software development is necessary for the difficult task of big data processing using SQL and NoSQL databases. In order to facilitate data organization and horizontal growth, SQL databases were developed [10]. In contrast, NoSQL databases can effectively handle massive volumes of unstructured data and provide horizontal scalability. Which paradigm is ideal depends on the demands of the organization, but picking the right one isn't always simple. The main distinction between SQL and NoSQL databases is in their respective database designs. The use of a mixed-model strategy is also common across all NoSQL database types.

2.1 SQL Databases

Research work on SQL query optimization and performance has mostly focused on Figure 1 shows the evolution of enterprise, production, parallel databases, and big data during the last several years. Database locking and data loss may occur as a result of inefficient and incorrectly configured queries that require a lot of system and server resources. Data mining is identifying the most important and connecting them in a sensible way out of the main data set, rather than keeping the raw information collected [11]. When optimizing a query, this aim to do so in the best way, so it costs and uses the fewest resources. The algorithms in data mining thoroughly search and analyze large amounts of data to bring out important information and knowledge. Object databases and XML have never been able to get the degree of popularity that RDBMS has [4].

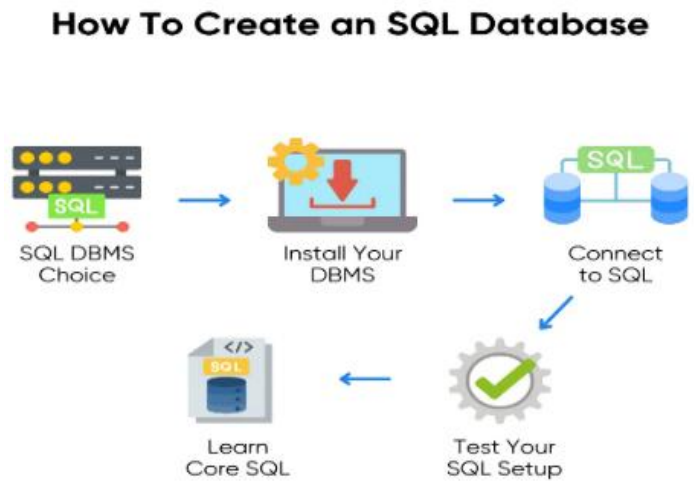

Figure 1: SQL Database

2.2 NoSQL Databases

NoSQL using Mongo DB, and compares the query response of both MySQL and NoSQL databases, concluded that results of NoSQL databases are faster than MySQL, and document-oriented storage is suitable to hold the health records and finally suggested the NoSQL is the best fit for large-scale applications like EHR typically hold a large amount of patient data. The importance of schema design for NoSQL Databases because it becomes popular for high performance and high Scalability and availability they can provide [12][13]. But it's not easy to design schema for large volume databases because there is no standard data type format available for heterogeneous data which was generated by a huge number of internet users. and also developed a standard model for Cassandra data storage. They proposed a new concept called “NoSQL Schema Evaluator (NoSE) “can provide automatic schema design process model for NoSQL databases. Figure 2 shows the No SQL database.

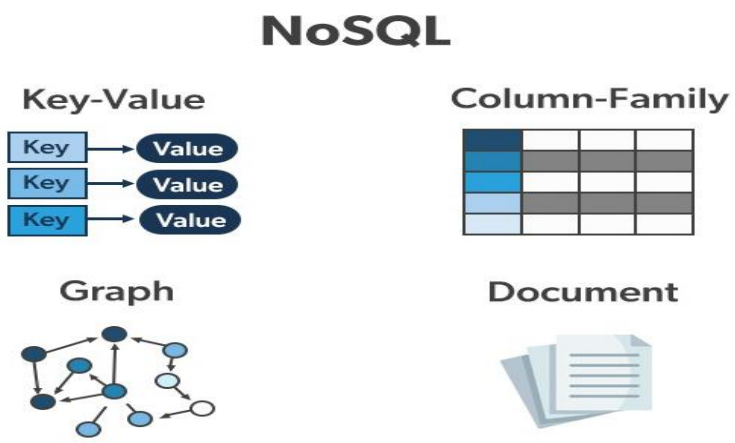

Figure 2: NOSQL Database

2.3 Compare SQL and NoSQL

One of the most established types of database models is the relational data model. It may write queries in its special language, and they have a set schema, vertical scalability, consistency, and durability as fundamental characteristics [14]. At the same time, the advancement in information technologies and much more data recording brings about Big Data, causing difficulties when using SQL databases. A new breed of databases known as NoSQL is emerging as a solution to the problem of massive amounts of semi-structured and unstructured data. In contrast to SQL databases, this article will focus on NoSQL databases and its benefits and drawbacks by following a systematic review of the literature. According to the chosen research questions, the strongest points of NoSQL were highlighted, and at the same time, the obstacles it encounters related to SQL databases in operation were also noted. Findings of the research were reported, and their meanings explained.

2.3.1 Importance of NoSQL

As soon as it comes to managing massive, diverse, and dynamic data sets, NoSQL databases are the way to go. They find widespread use in decentralized systems and cloud databases [15]. With NoSQL databases, there is no need to use fixed schemes and deal with lots of other restricting factors. The main reason for their creation was to give people an alternative option to the age-old relational databases. Scalability, handling errors, and availability play the main role in choosing a NoSQL database. They don't stick to the rigid structure of RDBMSs, which makes certain that if one part of the database breaks, the others continue to work as described by the term "fault tolerance". Built-in storage redundancy is a feature enjoyed by data and functions too. Each database in NoSQL is slightly different from the others because there are four basic types altogether.

- **Graph database:** In this kind of database, graph theory serves as the foundation. Case in point: Titan and Neo4j.
- **Key-Value store:** Key and value are the two components of data that are stored in this database. Redis, DynamoDB, and Riak are a few.
- **Column store:** In this case, data is organized into columns. HBase Big Table and Cassandra are two examples.
- **Document database:** Databases like this one are an improvement on key-value storage. This is where documents containing data in sophisticated forms (like JSON) are kept. Take MongoDB and CouchDB as examples.

3 REQUIREMENTS OF E-COMMERCE WEB APPLICATIONS

The new retail e-commerce platform using web application is needed which suited for advanced requirements to flexible and agile service combination. This paper developed the reference structure of effective pluggable service platform-based e-commerce using web application. Here, evaluated the present available solutions for online shop retail e-commerce platform and combination of platforms in market. Based on business method of e-commerce platform, various legacy elements are introduced in application layers.

3.1 E-Commerce Facilitators

Online shopping is referred to as e-commerce. The term describes the exchange of goods and services over electronic networks, most notably the internet. Through the use of EDI and other kinds of electronic data interchange and the internet, to conduct business is known as electronic commerce. In electronic commerce, the vendor's website serves as a platform through which the buyer and seller do business online [16].

3.1.1 Internet

Growing e-commerce is a result of the widespread availability of the internet. These days, almost everyone can't imagine living without their smartphone and the internet. The internet has evolved from a simple information source into a vital medium for commerce, education, communication, and even the hiring of professional services (such as those of physicians, plumbers, and carpenters) [17]. Additionally, the use of digital platforms is facilitating improved customer connections, leading to a significant reduction in waste and the promotion of environmentally conscious businesses, leading to a leaner and smarter supply chain.

3.1.2 Payment Gateways

The ability to pay for goods and services online, in physical stores, or via mobile devices is made possible by a service known as a payment gateway, which is an application service provider for e-commerce [18]. Payment methods, which include electronic money transfer, online banking, credit cards, and debit cards, are a crucial component of internet commerce. Payment gateways are essential for the long-term viability of e-commerce as the globe shifts away from cash and towards digital currency.

3.1.3 Analytics

Analytics provides a system for turning data into helpful information to make the best decisions. With analytics, businesses can gather, sort, study, and share information on all their clients' activities. Since there is a lot of data now, the companies have to use analytics to learn how customers behave. Any changes to the channel mix online and details about its success or failure must be

accessible to retailers in real time. Simple analytics are included by E-commerce companies like average order value or basket size, but they need well-built analytics to get meaningful insights about their consumers.

3.1.4 Social Media

There is an increasing number of companies using social media to advertise their goods. Social media websites and applications let people use their phones to exchange information and messages on the internet. Social media is now more important for building brands and telling customers about what is on offer. Customer service also makes it simple for people to comment on their goods or service. It makes it possible to develop a trusted user group, promote the brand, use ads, and encourage people to mention the business.

3.1.5 Autonomous Vehicles

Cars that can operate independently of a human driver are known as autonomous cars. These vehicles employ technologies such as AI, sensors, and GPS to do this. The arrival of the autonomous vehicle is drawing near. Buyers of autonomous cars will have more leisure time to do things like surf the web, check email, and buy online, and see ads everywhere. An abundance of opportunities for digital marketing will arise as a result of self-driving vehicles [19]. Businesses may use this data to target a certain demographic by tracking their online behavior (such as searches and purchases) [20].

3.2 Benefits and Challenges of E-Commerce Industry

In different settings, the phrase "E-commerce" may mean different things. The most common explanation is that e-commerce occurs when businesses and people transact business using the internet to buy and sell goods and services [21]. Various market sectors heavily use computers, cell phones, tablets, as well as other smart devices for online purchases.

- Almost any product or service may be bought via internet commerce. Products like books, music, and airline tickets fall under this category, as do services related to money, such as internet banking and stock trading.
- Especially for smaller businesses and other organizations with a smaller distribution area, e-commerce has opened up a wider market for their products and services by providing more efficient and less expensive distribution methods.
- In addition to the company's conventional brick-and-mortar stores, Target now has an e-commerce platform where customers can purchase products such as t-shirts, coffee machines, toothpaste, and action figures without ever leaving their homes.
- The whole purchasing process for customers has been supposedly expedited by electronic commerce, according to Customers may shop from the convenience of their own homes instead of enduring the hassle of going to physical establishments. There will be much less waiting around and faster transactions as a result. Members' operating expenditures were shown to be reduced via e-commerce, according to Chan et al.
- Traditional shopfronts are becoming obsolete for the majority of companies as a result of the proliferation of internet purchasing. There are a lot of expenses that go into operating a retail outlet, covering expenses like as rent, electricity, and other bills, as well as staff remuneration. These costs are irrelevant since the whole operation takes place over the internet. Chakraborty et al. state that among the top things about buying online is that customers may personalize their experience to their liking. Shoppers are free to peruse a wide variety of products in their quest to locate what they need [22][23].

3.3 Web Application Characteristics

The list of characteristics discussed shows factors that researchers deem significant to how easy a web application is to use. Usually, the concept of usability is defined by looking at the impact of users, tasks, technology, and context. All the characteristics will be organized into these four factors reviewed.

- **Users:** Users affected by a Main user, secondary users, user communities, purchasers, and surrogate users are the many components that make up a web application. A web application’s primary users should be checked for their skills, which can grow as time goes on: individuals are novice, then advanced beginners, then competent, and at last experts.
- **Task:** The manner in which tasks are performed, their content, the manner of interaction with the program, and the layout of the interface all impact how usable it is. All of these features guide the web application’s usability, based on learnability, user efficiency and satisfaction of users.
- **Technology:** Web database gateways, online form builders, and easy-to-use tools for publishing databases; such applications are created from dedicated models. HTML exports and publications of presentations can be accomplished with the help of Microsoft PowerPoint’s publishing wizard. CSS makes it possible to use limited design, interaction, and appearance in the website.
- **Context:** An industry classification in the specific requirements of a sector in terms of usability are highlighted by a web app. As a result, financial services must centre on security, while web applications from the government should main on accessibility [24].

4 SQL VS. NoSQL IN HIGH-TRAFFIC SCENARIOS

A look into how NoSQL and relational (SQL) databases interact is one of the most crucial factors to take into account when choosing a database, as shown in Figure 3. Even if each alternative is feasible, buyers should consider a few differences before making a decision. Server components like CPU, RAM, and SSD can usually be scaled since Vertical scalability is a feature of SQL databases. Vertical scaling is not an option with NoSQL databases. Therefore, it may add more servers or fragment (data partition), NoSQL database to expand its capacity. Therefore, why is it still difficult to choose the instance that needs the least amount of runtime and is best suited for a certain application [25]. Reason being, data to be sent over the internet will be represented metaphorically by a virtual space in online systems. To find out which model is best for you, it has to compare SQL-oriented database engines. In contrast to NoSQL databases, which may be expanded horizontally, SQL databases are designed for non-productive data and provide it in an organized format. Therefore, automation of organizational operations is also the responsibility of workload management solutions. This means that these solutions carry out tasks without the need for human intervention. Businesses who are aiming to improve the efficiency of customer service delivery and employ continuous delivery methodologies will inevitably encounter them [4].

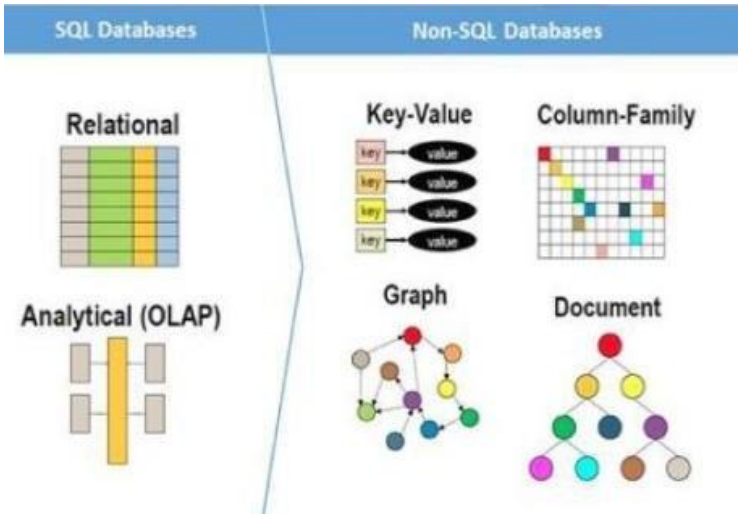

Figure 3: SQLVS NOSQL

Performance assessments on various clusters, including both cloud and on-premises systems, allow for this comparison. Included in the tests are common database operations, including inserting, selecting, and deleting records. The research shows that different database management systems work well for different kinds of tasks. A thorough evaluation of several aspects, including but not limited to performance and scalability, must precede the decision. The originality of this research is in the ways it compares and focuses on the cost-effectiveness of three popular database management systems, evaluates their performance in different environments, and determines their scalability.

4.1 Traffic Scenario

A hybrid simulation that completely combines and synchronizes two popular simulators, a complicated 3D simulator and a tiny, multi-modal traffic simulator, is the suggested solution. Using the provided software tool, one may model a fully autonomous vehicle, complete with sensors, dynamics, and control layers, in a scenario with heavy traffic. Thanks to the hybrid simulation's bidirectional integration, the ego-vehicle can observe and interact with other cars in the 3D simulator while all other vehicles in the activation of traffic simulator may be detected and acted upon [26]. Achieving integration required the creation of two interfaces; these interfaces synchronize the scenario, the states of all cars (including the ego-vehicle), and the time. One interface was established for each simulator. In a complicated merging scenario, the hybrid simulation's skills were put to the test using several ego-vehicle models and over 300 more automobiles [27].

Creating very severe traffic situations to evaluate the algorithms' and systems' performance and resilience is the fundamental benefit of simulation-based autonomous testing [28][29]. Traditional methods of creating or extracting test cases from real-world data are laborious, error-prone, and much inferior to testing in actual environments. Autonomy testing must be able to efficiently simulate realistic and varied dynamic traffic conditions. Also, rule- or deep-network-based approaches may struggle to meet the demands for interpretability, controllability, and diversity in scenario production all at once. Taking cues from the mechanisms of mutation and genetic inheritance in artificial intelligence, it presents SceGene, a system for the dynamic development of traffic scenarios. SceGene uses natural selection to regulate the course of generation and biological processes like mutation and crossover to swap out scenario topics.

SceGene has three main parts:

- An alternative way of depicting the characteristics of the traffic situations.
- An innovative method for creating novel scenarios via the use of mutation, selection, and crossover.

- A technique for fixing unusual situation data using the microscopic driving model. Results from tests conducted on the publicly available traffic scenario dataset prove that SceGene is capable of producing realistic and varied situations in a way that is both controllable and easy to understand, greatly enhancing the efficacy of autonomous testing conducted via simulation [30].

4.1.1 Novel Algorithms

It provides simulation results based on MATLAB/Simulink and offers novel strategies to guarantee high traffic capacity. Its prior work included the proposal of novel techniques that use anticipatory information to reduce the impact of communication delays on platoon string stability. As a prerequisite for achieving high traffic capacity, this study takes into account the need of maintaining a consistent distance between the leaders of platoons.

It evaluates the new algorithms using MATLAB/Simulink simulations of various situations. The findings show that the methods work as advertised, ensuring manageable levels of traffic and vehicle density without causing gridlock [31].

4.2 Flow Traffic Network

There is a lot of activity on the network. Taking into account information sent across an IEC 61850 network, including GOOSE messages, Sampled Values, and PTP, this study illustrates the performance of the switch using real-life situations. To guarantee digital communication performance, even in the most extreme circumstances, it is necessary to specify switches for each application [32].

5 LITERATURE REVIEW

This literature review examines recent studies comparing SQL and NoSQL databases, focusing on performance, scalability, and suitability for different data types. It highlights key findings, challenges like cost and real-time processing, and limitations related to specific environments, offering insights into database management approaches for diverse applications.

S, Sai Kapuluru and B (2025) Attackers may compromise applications by interfering with their queries to NoSQL databases, a security flaw known as NoSQL injection. In some cases, these types of attacks may lead to the execution of code on the server, data extraction or modification, a denial of service, or both. Unlike traditional SQL databases, NoSQL databases use varied query languages and data structures, which results in different types of injection vulnerabilities. The two primary forms of NoSQL injection are syntax injection, where attackers manipulate query syntax similar to SQL injection techniques, and operator injection, where attackers leverage query operators to manipulate queries [33].

Samarta, Gunawan and Syahputra (2024) deals with issues regarding which among database types- SQL or NoSQL-is more effective in Big Data environments. The paper consequently benchmarks the key performance indicators such as storage capacity, query execution time, and scalability through a systematic review of literature. SQL databases have been found to be robust with respect to preserving the integrity and consistency of transactions while dealing with structured data and complicated searches. Nevertheless, when dealing with unstructured data, their scalability and flexibility are severely lacking, making them less than ideal for some big data uses. In contrast, NoSQL databases excel at facilitating both availability and flexibility, handle unstructured data in very large volumes, and give support for a variety of data models [34].

Chai and Qin (2024) outline a case study aimed at identifying the most effective method for improving application performance with large and continuously expanding datasets. To achieve this, the query performance of SQL and NoSQL systems are compared. The comparison involves measuring the runtimes of queries executed on SQL and NoSQL databases hosted in the cloud, using the TPC benchmark. The experiment assesses the response times of both database types, ultimately indicating which method performs better [35].

Pletnev et al. (2024) considers methods of determining the average speed, traffic intensity, density and composition of traffic flow using high-precision positioning. It describes the general principle of operation, techniques and advantages of using HPPS and technology for determining traffic flow parameters using HPPS, and further application of the data obtained for traffic optimization. The conclusion describes the advantages and disadvantages of using high-precision positioning subsystems for determining traffic flow parameters and further development prospects [36].

Yedilkhan et al. (2023) seeks to explore cutting-edge approaches to cost-effective scalable database administration. The research looks at PostgreSQL, a conventional RDBMS, and two popular NoSQL databases, MongoDB and Cassandra DB. Performance assessments on various clusters, including both cloud and on-premises systems, allow for this comparison. Included in the tests are common database operations including inserting, selecting, and deleting records. According to the research, different database management systems excel in handling different types of tasks [37].

Montolalu, Rochimah and Siahaan (2023) introduces an approach for building an object mapping framework on SQL and NoSQL databases. They build a framework by carrying out concept mapping, syntax conversion, and developing object database mapping. Object database mapping is developed using chaining method and active record design pattern. The framework was tested using the

hospital information system billing module. The results of this research demonstrate that the constructed framework can execute CRUD query commands on three distinct types of databases: MySQL, MongoDB [38].

Table 1 summarizes studies on database systems, comparing SQL and NoSQL approaches, key findings, challenges faced, and limitations, highlighting performance, scalability, and application-specific considerations across various environments.

Table 1: Summarizes Key Studies Comparing SQL and NoSQL Database

Author	Approaches	Key Findings	Challenges	Limitations
S, Kapuluru and B. (2025)	Analyzes NoSQL injection types (syntax and operator) and their impact on applications.	NoSQL injection can bypass authentication, alter data, or execute malicious code due to diverse query structures.	Addressing heterogeneous injection vectors in different NoSQL platforms.	Lack of standardized prevention techniques across varied NoSQL databases.
Samarta, Gunawan and Syahputra (2024)	Research on Big Data, focusing on SQL and NoSQL databases, is examined in detail.	SQL is reliable for structured data and integrity; NoSQL excels in scalability and handling unstructured data.	Data type and application requirements should be considered while selecting a database.	Benchmarks may not reflect real-world hybrid data scenarios.
Chai and Qin (2024)	Case study using TPC benchmark to compare cloud-hosted SQL and NoSQL databases.	NoSQL performs better in large, continuously growing datasets in terms of response time.	Balancing performance with consistency in high-volume environments.	Study focused only on query runtime; didn't explore availability or fault tolerance.
Pletnev et al. (2024)	Uses high-precision positioning systems (HPPS) to analyze traffic flow.	HPPS enables accurate measurement of traffic parameters and flow optimization.	Integration of HPPS with existing traffic systems.	Study is domain-specific; not directly related to database performance.
Yedilkhan et al. (2023)	Testing the efficacy of PostgreSQL, MongoDB, and Cassandra on both cloud and on-premises clusters.	NoSQL is optimized for specific operations; PostgreSQL excels in transactional consistency.	Aligning use cases with appropriate DBMS choice.	Hardware variability and specific workloads may influence performance outcomes.
Montolalu, Rochimah, and Siahaan (2023)	Developed object mapping framework for SQL and NoSQL (MySQL, MongoDB).	The framework supports CRUD operations across different DBMS using chaining and active record pattern.	Designing universal syntax mapping for multiple DB types.	Tested only on hospital billing module; generalizability may be limited.

6 CONCLUSION

SQL and NoSQL databases have distinct advantages depending on application requirements in high-traffic e-commerce systems. SQL databases provide robust support for transactional integrity, structured data management, and complex querying, which is critical for operations requiring strong consistency. However, as the volume and variability of data grow in modern e-commerce environments, when compared to relational databases, NoSQL ones are more performant, available, and scalable. The horizontal scalability and flexible schema designs of databases like MongoDB and Cassandra make them ideal for managing massive amounts of unstructured data. The hybrid use of both SQL and NoSQL databases can be beneficial, leveraging the strengths of each. Moreover, simulation models such as SceGene and high-traffic testing environments are crucial for evaluating system robustness and reliability in real-world applications.

Future developments should focus on automated schema design tools, cross-database integration frameworks, and deeper analytics integration for adaptive performance tuning.

Future work in this area should focus on enhancing the adaptability and efficiency of database systems in high-traffic e-commerce environments. One promising direction is the development of automated schema design tools for NoSQL databases, which would help manage the complexity of schema-less structures while optimizing performance.

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