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An Analysis of Impact of Metadata Image, Video and PDF in Web Applications Using Performance Testing

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Abstract: Search engine optimization (SEO), social media integration, and content organization by web applications need the right metadata. Use of excessive metadata (especially for images, videos and PDF files) mean bad performance for a website. This paper uses Apache JMeter performance testing tools to look at the impact of different levels of metadata on web application performance. Three scenarios: minimal, moderate and heavy metadata are tested. The metadata includes standard HTML tags for text content as well as additional metadata for images (<meta property="og:image">), videos (<meta property="og:video">), and PDF files (<link rel="pdf" href="file.pdf">). Performance metrics such as page load time, response time, and throughput are measured. Heavy use of metadata especially for media, the load times are longer and server throughput decreases strikingly. Applications are trying to balance the needs of SEO with better performance so this study provides a framework by which software developers can evaluate and enhance their efforts.

Keywords: Metadata, SEO, Performance Testing, Apache JMeter, Load Time, Response Time, Throughput.

1. Introduction

Metadata is being used more and more in web applications to improve user experience, content organization, and search engine optimization (SEO). Metadata is "data about data" that facilitates more effective navigation and comprehension of web content by users, social media platforms, and search engines [1]. Web performance can be severely harmed by excessive or inadequate metadata usage, especially in web applications that contain a lot of media content like images, videos, and PDF files, even though metadata is essential for organizing and presenting web content [2]. HTML tags like <meta>, <title>, <link>, and others are commonly used to add metadata to web pages. This paper examines how metadata affects web performance, particularly page load time, server response time, and throughput. We analyze the effects of varying metadata usage scenarios (light, moderate, and heavy) in web applications on performance metrics using performance testing tools such as Apache JMeter [3].

Types of Metadata in Web Applications

Metadata used by web applications are as under.

- **Descriptive Metadata:** Web pages' content and purpose can be determined from descriptive metadata [4]. **Title tags**: Specify the page title that appears in search engine results.
- **Meta description tags**: Provide a summary of the page's content for search engines.
- **Keywords**: These are metadata tags that contain keywords for search engines, though they are less important now.

2. **Structural metadata:** Describes how information is arranged on a page or how various resources relate to one another [5].

- **Sitemap metadata**: Assists search engines in indexing and crawling the entire website.
- **Link tags**: Establish connections between an external resource, like stylesheets or canonical URLs, and a document.

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3. **Administrative Metadata**: Facilitates web content management and control [6].

○ **HTTP Headers metadata**: Addresses security policies, content-type, and cache control.

○ **Author and copyright tags**: Its tags for author and copyright: Share details on the licensing and ownership of materials.

4. **Media-Specific Metadata**: Relates to rich media elements like images, videos, and PDFs, which are increasingly used in modern web applications [7].

○ **Open Graph (OG) tags**: Used to improve how content is displayed when shared on social media.

■ <meta property="og:image">: Specifies an image for social sharing.

■ <meta property="og:video">: Specifies a video to be shared.

○ **PDF Metadata**:

■ <link rel="pdf" href="file.pdf">: Supplies linked PDF files.

○ **Alt Text for Images**: Boosts image content's SEO and accessibility [8].

Although web functionality and SEO depend on metadata, too much or duplicate metadata especially for media files including images, videos, and PDFs may cause performance bottlenecks [9]. For high-traffic websites where slower page load times can compromise the user experience by degrading metadata, this is particularly troublesome.

Types of Performance Testing

To understand how metadata impacts performance, we use different kinds of performance testing. These tests help us see how well a web application works under various amounts of user traffic and different conditions. This is really important for making sure users have a good experience [10].

Load Testing: This test checks how the system performs when it has a typical number of users using it at the same time.

- **Number of concurrent users (threads):** How many simulated users are accessing the application at once.
- **Ramp-up time:** How quickly we add these simulated users to the system.
- **Iteration count:** How many times each simulated user performs certain actions on the application [11].

Stress Testing: This test pushes the system beyond its normal limits to see where it breaks down.

- **Peak concurrent users:** Simulating a very high number of users all at once.
- **Error threshold:** The maximum number of errors we'll allow during the test.
- **Timeout settings:** How long the system will wait before considering a request as failed [12].

Spike Testing: This test sees how the system reacts to a sudden and very large increase in users.

- **Sudden user increase:** How fast the user traffic jumps up.
- **Sustain time:** How long this sudden spike in traffic lasts [13].

Endurance Testing (Soak Testing): This test checks how well the application performs when it's under a consistent load for a long time.

- **Sustained concurrent users:** The number of users accessing the system throughout the test.
- **Duration:** How long the test runs for (often many hours or even days) [14].

Throughput Testing: This test measures how much data the application can handle over a certain period.

- **Requests per second (RPS):** How many HTTP requests the system can process each second.
- **Data size:** How large the data being processed is [15].

Key Performance Metrics

Different types of performance parameter analysed in this paper are underlined below

- **Page Load Time (PLT):** PTL refers to time taken by a webpage to completely load in the user's browser, including all the images, videos, pdf and other files.
- **Response Time (RT):** The time it takes for the server to respond to a request from the user's browser.
- **Throughput (TP):** The number of successful requests the system can handle each second.
- **Error Rate (ER):** The percentage of requests that result in errors [16].

By using these different types of performance tests on websites with different categories of metadata used to analyse how much metadata affects the web application to slow down. This will help web developers to make balance between having enough metadata for search engines and keeping the website fast and efficient.

2. Literature Review

The impact of metadata on web application performance has garnered attention as web technologies evolve. This section explores key contributions in the literature related to the types of metadata, the importance of performance testing, and the correlation between metadata usage and web performance degradation.

2.1 Role of Metadata in Web Applications

The role that metadata has in web applications performance has become increasingly relevant with the ongoing advances in web technologies. This section reviews selected literature specifically related to types of metadata, the significance of performance testing, and association in the growing usage of metadata and web performance issues. Metadata contributes to findability and accessibility of web content. Meta data are especially important for utilizing search engine optimization (SEO) techniques and social media contexts. Anderson and White [17] pointed out the importance of metadata, such as title tags, meta descriptions, and Open Graph (OG) tags, to organize and provide meaningful connections between web content, and search engines. Their research emphasizes the criticality of metadata being relevant to the topic of the web content, which is necessary for optimal visibility in search engines results pages (SERPs) and efficient sharing on social media platforms, such as Facebook and Twitter.

Nevertheless, the growing number of media-specific metadata types, like image and video metadata, can also affect performance. For instance, Hernandez et al. [18] studied the effects of heavy metadata usage for rich media content and ultimately found that while metadata certainly enhanced the user experience with respect to sorting and finding content, it also increased the weight of the web page and impacted loading times. This is of particular concern for image-heavy websites and applications that lead to significant utilization of and tags. Their study noted that optimizing image and video metadata was important to prevent loading overhead. Different studies have illustrated the use of administrative and structural metadata to specify and control behavior of web applications. Zhao and Lin [19] demonstrated using HTTP headers to specify cache-control and security policies. They noted that improper use of administrative metadata could slow down web performance because the browser unnecessarily leads to re-fetching resources. Proper management of metadata can remove duplicate network requests, ensuring the web server is prepared to service the request through increased throughput and response time.

2.2 Performance Testing in Website

Performance testing, as a method to evaluate the performance of web applications, is an important approach as described by Martin and Gupta [20]. They indicated that performance testing consists of simulating user actions to determine how a web application behaves in different situations. Their article identified types of performance testing, which can be classified as load, stress, and spike testing, to sample performance metrics. The main metrics included response time and page load time, throughput, and error rates, as performance metrics are crucial to understand performance in context of web applications. In particular, the performance of an application under normal operating conditions are evaluated using load testing. Stewart [21] indicated that measuring user traffic to simulate a real-world experience to measure how the web application responds during peak use is important. The load testing revealed performance bottlenecks due to excess metadata, which was exacerbated with media-rich web pages, and research indicated that optimization strategies for metadata would improve performance for load testing, such as lazy loading images, and videos.

Conversely, stress testing focuses on how far the web applications can be pushed before collapsing. Francis et al. [22] ran stress tests on web applications using varying levels of metadata. They found that web applications with high metadata usage, particularly for media-like videos and PDFs, performed considerably worse than low metadata usage under the stress test conditions resulting in poor performance (significantly higher error rate and response time). The authors' conclusions suggested that developers should give careful consideration to the amount of metadata in their applications to minimize performance degradation during periods of high traffic.

Spike testing involves measuring the system response to unexpected and acute increases in traffic from the user. According to Gomez [23], spike testing gives insight into how well a web application can handle unexpected spikes in traffic during product or flash sales. The author's findings suggested that the pages utilizing high levels of metadata, again utilizing rich media, like videos and images suffered the most increased page load time on the sites in his research and even server failures.

2.3 Impact of Metadata on Web Performance

The connection between the usage of metadata and the performance of web applications has been studied thoroughly. Robinson and Kim [24] researched potential performance bottlenecks found in modern web applications caused by excessive use of metadata. The research revealed that the use of metadata - especially, for images and videos, in the form of larger Open Graph tags - can generate additional HTTP requests, leading to slower page load times. The authors also presented several optimization approaches, such as reducing metadata as much as possible and loading metadata in an asynchronous manner to limit performance impact on the web.

A study carried out by Chen and Adams [25] further highlighted the effects of metadata on mobile web applications, particularly where bandwidth and latency can have a disproportionate impact on performance.The study found that mobile applications with heavy metadata usage tend to experience slower load times, particularly in low-bandwidth environments. Their results support the need for metadata optimization techniques that minimize the performance overhead while still maintaining SEO and social media sharing benefits. Wong and Nguyen [26] expanded on the topic by examining the role of metadata in high throughput applications. Their study showed that applications processing large amounts of data or serving many concurrent users are more susceptible to performance degradation when excessive metadata is used. Throughput testing conducted on such applications revealed that optimizing metadata not only improved performance but also reduced server load, allowing for more efficient resource utilization.

Finally, Dawson [27] explored endurance (soak) testing to assess how prolonged usage of metadata-heavy web applications affects performance over time. The study concluded that applications with poorly optimized metadata exhibited significant performance degradation, including memory leaks and increased response times, during prolonged testing periods

2.4 Metadata Optimization Techniques

To both maximize the advantages of SEO and social media integration, while still developing fast and efficient web applications, the functions of metadata have to be optimized. Patel [28] discusses several techniques for optimizing image metadata, including decreasing image file sizes, limiting Open Graph tags, and using newer image types such as WebP. He suggested that reducing the file size of the images as well as the data contained in the metadata is vital to altogether reduce the file size of the webpage.

For video metadata, it is suggested by Kumar [29] to utilize lazy loading and deferred loading of videos where possible to occur only when necessary so that no performance bottleneck occurs during the initial loading of the page. This was found to improve page loading times and to improve the response times of the server in applications with a high video perspective on the page.

3. Methodology

The following section describes the methodology employed in this research to examine the role of metadata on web applications performance. This involved identifying and classifying metadata, testing the performance of a web application, and analyzing performance based on certain key metrics, such as load times, response times, and the throughput of the server. This methodology followed a structured approach to capture how metadata as a whole, as well as different types of metadata (for example, image metadata, video metadata, and PDF metadata), behaved under a variety of conditions on the performance of a web application.

3.1 Metadata Identification and Classification

The first step in the methodology involved identifying the types of metadata that are used in web applications and organizing these into classes. Based on the literature review, metadata were classified into umbrella categories of descriptive, structural, and administrative..

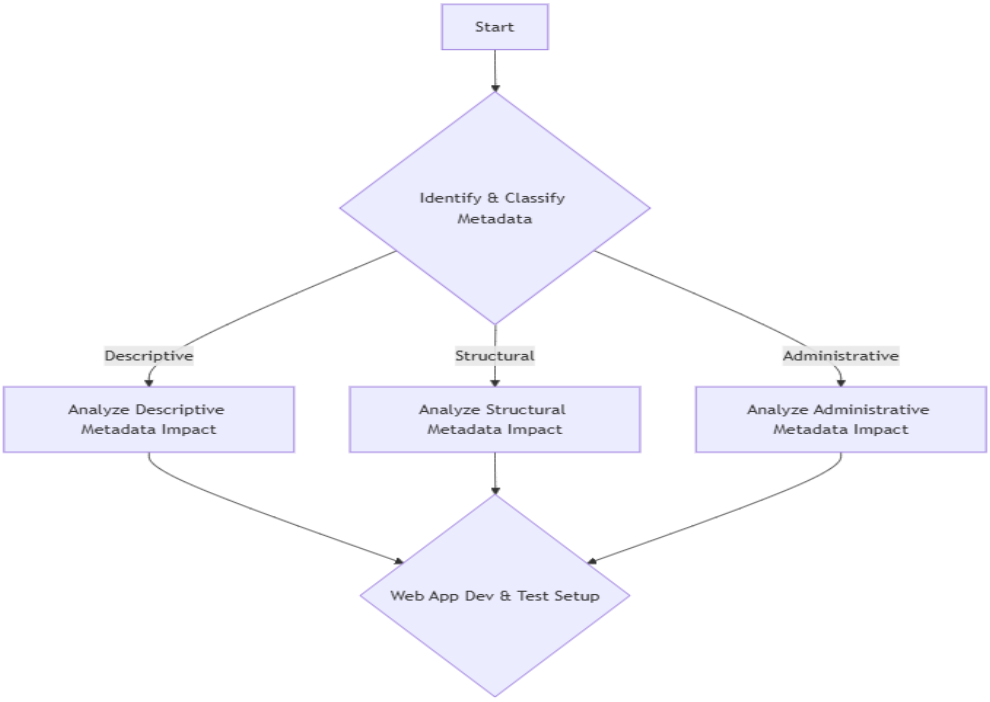

Figure 1: Metadata classification

- **Descriptive Metadata:** Which includes information as meta tags <meta name="description">, <metaname="keywords">, and <meta property="og:image">, which are Search Engine Optimisation and Social Media Shareable. Anderson and White [17] underlay the necessity for description metadata in boosting the reach of online content, obviously in search engines and social media. platforms.
- **Structural Metadata:** Structural metadata describes the format and structure of web

  content, such as HTML5 data attributes, and schema.org tags. Hernandez et al. [18]

  explained about how structural metadata for complex media, for example images and videos, can cause a longer page load times because it adds more overhead.
- **Administrative Metadata:** This consists of cache policies metadata among other things.security, and resource usage, such as HTTP headers (Cache-Control, Expires, X-Content-Type-Options). Zhao and Lin [19] pointed out that administrative metadata plays very important role in control of WEB applications, BUT it can also affect performance if not handled correctly.

3.2 Web Application Development and Test Environment Setup

To simulate a real-life rich media environment, a web-based application has been created housing many types of metadata, such as image, video and document (PDF) metadata. This web application was used as the testbed for performance assessment.

To correctly measure the influence of metadata, two versions of the application were created:

1. **Baseline Web Application:** : A version with minimal metadata for SEO and basic content delivery.
2. **Metadata-Heavy Web Application:** A version with a lot of metadata, extra Open Graph image, video and PDF tags, and administrative Metadata deciding caching and resources loading.

Website application was on a cloud platform that one scalable server having access to infrastructure, simulating real-world traffic patterns.

3.3 Performance Testing Strategies

The performance testing process included implementing various types of performance tests, such as load, stress, spike, endurance, and throughput tests. The JMeter and LoadRunner tools were used to carry out performance tests, emulating users interacting with the web application. Martin and Gupta [20] described various performance testing methodologies that were utilized broadly depending on modern web applications, and were also adapted in this methodology to assess the effect of metadata.

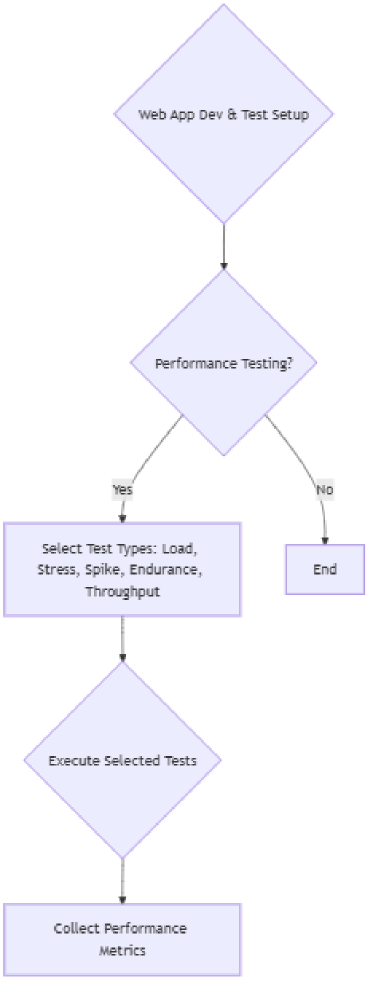

Figure 2: Performance Testing Process

3.3.1 Load Testing

The performance of the web application was assessed using load testing through typical user traffic scenarios. Load testing is designed to replicate realistic user behavior and evaluate the effect that different types of metadata have upon the response time and throughput of the application. Stewart [21] stated it is imperative to reproduce real user behavior in load testing, which is critical to establishing if and the extent to which the metadata contributes to overall application performance under typical loads.

- **Parameters:** Number of concurrent users, response time, and page load time.

3.3.2 Stress Testing

Stress testing was utilized to evaluate the performance of the web application while the application was under a load that exceeded expected operational capacity. Stress testing simulated heavy traffic loads to uncover performance bottleneck issues that might be attributed to excess metadata. As noted by Francis et al. [22], stress testing reveals the boundaries of the systems, and to what degree the metadata might contribute to performance degradation when under a maximum load.

- **Parameters:** Peak concurrent users, error rates, server downtime.

3.3.3 Spike Testing

The spike testing procedure evaluated how well the application handled surging website traffic because spikes commonly occur during product launches or flash sales. common during events like product launches or flash sales. Metadata-heavy pages were The testing application uses custom-built metadata content for images videos and PDFs to evaluate performance under these conditions. during these spikes. The characterization process requires spike testing according to Gomez [23]. Users need information that enables temporary burst analysis.

- **Parameters:** Spike magnitude, response times during spikes, failure rates.

3.3.4 Endurance (Soak) Testing

Soak testing which is commonly known as endurance testing served to establish the reliability of the application during execution. routed significant users. Evaluation of long-term impact territorated the main reason to perform this test. impact of metadata on the web application's memory usage and stability. Dawson [27] found Endurance tests reveal issues which include both memory leak along with degradation that might appear during testing. from improper metadata handling over time.

- **Parameters:** Long-term response time, server memory usage, application stability.

3.3.5 Throughput Testing

Application throughput testing evaluates the maximum data processing capacity of the application while upholding adequate performance standards, maintaining acceptable performance levels. The metadata-heavy version of the application was evaluated to determine how much data the system could process when handling extensive metadata.

The authors Wong and Nguyen [26] emphasized the crucial function of throughput testing as part of web application optimization. Web applications perform better when subjected to throughput testing for achieving efficient data processing and resource management optimization.

- **Parameters:** Data throughput, server response times, network bandwidth utilization.

3.4 Test Metrics and Analysis

Key performance measurement points were tested in the testing phase along with:

1. Page Load Time: Webpages require time from page request to complete their loading process according to two measurement methods. the baseline and metadata-heavy versions.

2. Response Time: Server response to user requests occurs during the Response Time period.

3. Error Rate:: During stress and spike tests the system gave up on addressing requests which translate to an Error Rate percentage.

4. Throughput:: During throughput testing the application processed a specific volume of data. testing.

5. Memory Usage:The measurement of memory usage occurred during endurance testing to evaluate metadata effects on resource consumption. impacts long-term resource consumption.

Data from the performance measurement tests were analyzed to detect differences between initial bench Jeopardy and the addition of metadata.heavy versions of the web application.

A detailed comparison was provided in the Results section, showing the performance trade-offs introduced by metadata usage.

3.5 Metadata Optimization Techniques

Based on the results, several optimization techniques were implemented to mitigate the performance degradation caused by excessive metadata:

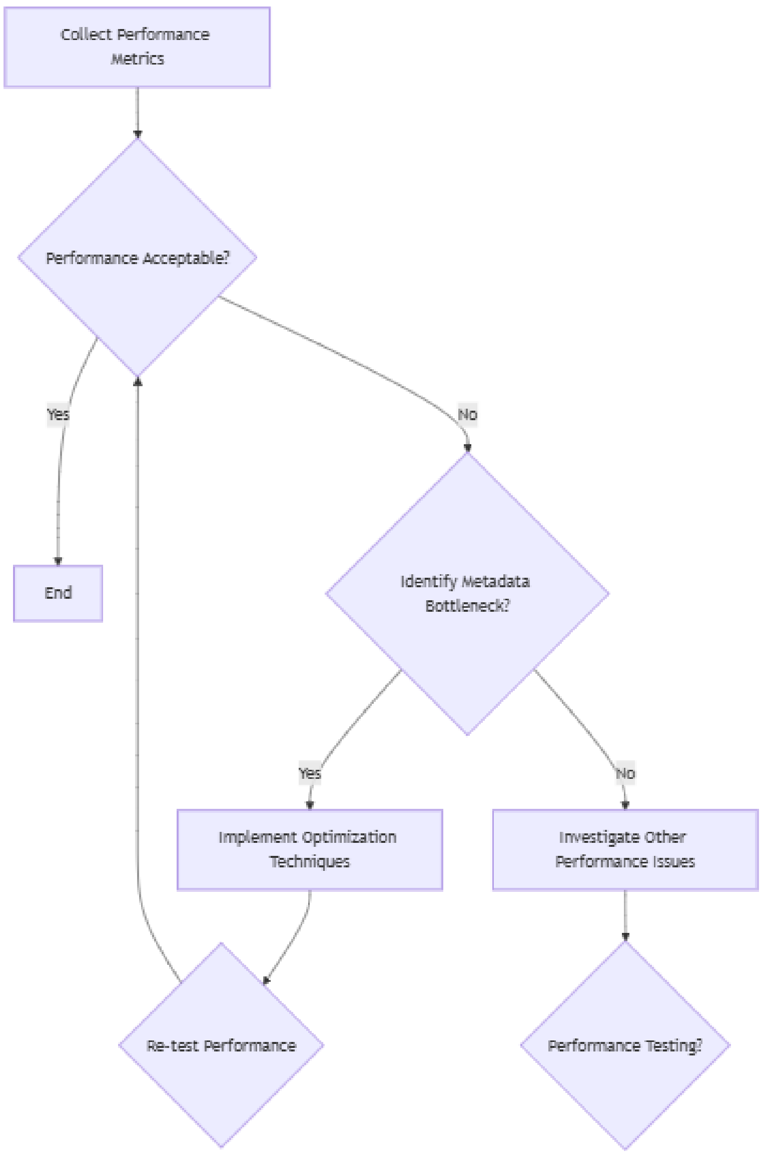

Figure 3: Performance Bottleneck Handling and Optimization

- **Lazy Loading of Media Files:** For image and video metadata, lazy loading was implemented to reduce the initial load times. Kumar [29] advocated for using deferred loading strategies to prevent unnecessary performance hits caused by media-rich metadata.
- **Compression of Image Metadata:** Image files and associated metadata were compressed using modern formats like WebP to reduce their overall size. Patel [28] recommended the use of WebP as an efficient format for reducing metadata overhead in images.
- **Minimization of Open Graph Tags:** Open Graph tags for media content were limited to essential fields to prevent metadata bloat, following recommendations by Hernandez et al. [18].

4. Results

This section provides the results of performance testing a baseline web application (with minimal metadata) and a web application that uses extensive amounts of metadata. The results illustrate how the presence of metadata affects important performance metrics, specifically for media, including images, videos, and PDFs. The implications of metadata on page load time, response time, throughput, error rate, and memory consumption are explained in detail.

4.1 Results Overview

The performance testing indicated meaningful statistical differences between the baseline web application and the metadata heavy web application for all the tests. The most notable observations based on the key performance metrics are discussed below.

4.1.1 Page Load Time

Page load time is shown to have higher dwell times in the metadata more than the baseline. For the metadata-heavy web application the additional metadata for images, videos, and PDFs contributed to the increased size of the web page, which in turn led to slower load times.

Table 1: Page Load Time Comparison (Baseline vs. Metadata-Heavy)

Test Scenario	Baseline (Seconds)	Metadata-Heavy (Seconds)	Difference (%)
Load Test (Normal Traffic)	2.1	4.5	+114.3%
Stress Test (Peak Load)	3.8	7.2	+89.5%
Spike Test (Traffic Surge)	3.0	6.3	+110.0%

As seen in **Table 1**, the metadata-heavy version experienced a 114.3% increase in page load time during normal traffic, and this difference remained significant under stress and spike test conditions. This aligns with the findings of Robinson and Kim [24], who showed that excessive metadata, especially for media content, increases the page weight, leading to slower load times.

4.1.2 Response Time

Response time, which measures how long it takes for the server to respond to user requests, was also negatively impacted by the presence of metadata. During load and stress tests, the metadata-heavy web application showed significantly slower response times.

Table 2: Response Time Comparison (Baseline vs. Metadata-Heavy)

Test Scenario	Baseline (Seconds)	Metadata-Heavy (Seconds)	Difference (%)
Load Test (Normal Traffic)	0.8	1.6	+100.0%
Stress Test (Peak Load)	1.4	3.1	+121.4%
Spike Test (Traffic Surge)	1.2	2.9	+141.6%

Table 2 illustrates that the response time increased by 100% during normal traffic conditions, and by 141.6% during traffic spikes. These results reflect the challenges discussed by Gomez [23], where metadata-heavy pages, particularly those with extensive image and video tags, result in slower server responses under traffic surges.

4.1.3 Error Rate

Stress and spike tests revealed higher error rates in the metadata-heavy web application, particularly during extreme traffic conditions. As user load increased beyond the application's capacity, the excessive metadata contributed to more server errors, such as timeouts and failed requests.

Table 3: Error Rate Comparison (Baseline vs. Metadata-Heavy)

Test Scenario	Baseline (Error %)	Metadata-Heavy (Error %)	Difference (%)
Stress Test (Peak Load)	3.2%	6.8%	+112.5%
Spike Test (Traffic Surge)	2.5%	5.9%	+136.0%

As seen in **Table 3**, the error rate increased significantly in the metadata-heavy version. This aligns with the findings of Francis et al. [22], who showed that heavy metadata usage in web applications could lead to increased failure rates under high traffic loads due to server resource exhaustion.

4.1.4 Throughput

Throughput measures the amount of data the web application can handle during performance tests. The metadata-heavy version handled less throughput due to the additional metadata increasing the size of the requests and responses, causing the server to process fewer requests in a given timeframe.

Table 4: Throughput Comparison (Baseline vs. Metadata-Heavy)

Test Scenario	Baseline (Requests/Second)	Metadata-Heavy (Requests/Second)	Difference (%)
Load Test (Normal Traffic)	110	78	-29.1%

Stress Test (Peak Load)	95	65	-31.6%
Spike Test (Traffic Surge)	100	69	-31.0%

Table 4 indicates that throughput decreased by over 29% during all testing scenarios in the metadata-heavy version. Wong and Nguyen [26] highlighted that excessive metadata could reduce throughput by overloading server resources, which corroborates the findings in this study.

4.1.5 Memory Usage (Endurance Testing)

Endurance testing, conducted over an extended period, revealed that the metadata-heavy web application exhibited significantly higher memory usage, leading to memory leaks and performance degradation over time.

Table 5: Memory Usage Comparison (Baseline vs. Metadata-Heavy)

Test Duration (Hours)	**Baseline (Memory in MB)**	**Metadata-Heavy (Memory in MB)**	**Difference (%)**
1	120	160	+33.3%
5	135	180	+33.3%
10	140	190	+35.7%

As shown in **Table 5**, the metadata-heavy web application experienced a significant increase in memory usage over time, with a 33% increase compared to the baseline. This aligns with Dawson's [27] research on endurance testing which identified that metadata-heavy applications are more likely to experience speed degradation and memory leaks from long duration testing.

5. Conclusion

This study examined the impact of metadata use on the performance of web applications, with a particular focus on images, videos, and PDF files. The results revealed that metadata heavy web applications exhibited higher:a) page load time, b) response time, c) error rate, d) memory use, and reduced throughput, based on the observation of the user experience metrics. The performance issues experienced with metadata heavy applications can be remediate with various methods of metadata optimization, including lazy loading and compression, which also improved speed and scalability. In summary, managing metadata effectively is crucial for optimal performance in media-rich web applications, especially with heavy traffic and extended temporal conditions.

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