Programmatic Search Engine Optimization in Localized Web Applications: A Case Study on a Firewood Marketplace App

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This thesis investigates the application of Search Engine Optimization (SEO), with a particular focus on Programmatic SEO (pSEO), in localized web applications to improve visibility in Google Search. Motivated by the development of a real-world firewood marketplace application, the study aims to identify effective SEO strategies for complex, multi-locale platforms.

A mixed-methods approach was adopted, comprising a literature review of SEO best practices, a qualitative content analysis of expert-authored sources on pSEO, and a case study implementing these techniques. The literature review highlighted strategies across on-page, off-page, technical, content, user experience, and local SEO, examined methods for measuring and maintaining SEO, and explored the use of AI in SEO. The review revealed a gap in academic research on pSEO. To address this, pSEO was defined and structured into a seven-step framework involving developing a strategy, keyword research, designing and building programmatic pages, creating high-quality content, managing sitemaps, acquiring backlinks, and maintaining the generated pages.

This framework was then applied to the case study, which demonstrated how SEO and pSEO techniques can be practically integrated into a modern multi-locale web application. Although the direct impact on search rankings was not empirically measured in this study, the findings suggest strong alignment between the identified best practices and high SEO audit scores. This research contributes to both academic literature and professional practice by developing a practical pSEO approach and demonstrating its application in a real-world context.

Key words: Programmatic, Search Engine Optimization, SEO, pSEO, localization, Web Application

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List of Abbreviations

AI	Artificial Intelligence
AJAX	Asynchronous JavaScript and XML
AMP	Accelerated Mobile Pages
API	Application Programming Interface
CDN	Content Delivery Network
CLS	Cumulative Layout Shift
CSR	Client-Side Rendering
CSS	Cascading Style Sheets
CTR	Click-Through Rate
DNS	Domain Name System
DOM	Document Object Model
FID	First Input Delay
GMB	Google My Business
HTML	HyperText Markup Language
HTTP	Hypertext Transfer Protocol
JSON	JavaScript Object Notation
LCP	Largest Contentful Paint
NAP	Name Address Phone Number
MPA	Multi-Page Application
pSEO	Programmatic SEO
SEO	Search Engine Optimization
SERP	Search Engine Results Page
SPA	Single-Page Application
SSG	Static Site Generation / Static Site Generator
SSL	Secure Sockets Layer
SSR	Server-Side Rendering
TBT	Total Blocking Time
TLD	Top-Level Domain
UI	User Interface
UX	User Experience

1 Introduction

In today's digital landscape, visibility in Google Search plays a crucial role in the success of online services. As the most widely used search engine globally, with its market share in January 2025 at around 90% [32], Google remains the dominant search engine through which a significant majority of users discover websites, products, and services. For web applications in particular, securing prominent placement in search results is essential for attracting users, generating traffic, and maintaining a competitive edge. Search engine optimization (SEO) offers a range of strategies and techniques to improve this visibility in search engines. However, implementing effective SEO for modern, often complex web applications—especially those serving multiple locales—presents unique challenges that require specialized approaches.

To explore these challenges in a practical context, this thesis investigates how SEO can be used to improve the visibility of localized web applications in Google Search results. The research is limited to Google Search due to its overwhelming dominance in the search engine market. Additionally, many core SEO techniques are applicable across different search engines, although their effectiveness may vary depending on each engine's algorithms and ranking factors. The research is motivated by the practical development of a real-world application: a firewood marketplace web app that allows users to buy and sell firewood. Since the service relies heavily on organic search traffic to reach its target audience, implementing effective SEO is critical for the success of the application.

The research begins by reviewing the foundations of SEO and its role in web application development. Particular focus is given to programmatic SEO (pSEO), a modern, data-driven approach that enables the creation of SEO-optimized pages at scale using automation and structured templates. Although pSEO is increasingly used in industry, academic literature specifically addressing its techniques and applications remains scarce. To address this gap, the thesis includes a qualitative content analysis of online materials authored by pSEO experts. The insights and strategies examined in this research are demonstrated through a case study of the firewood marketplace app, making the work both theoretically grounded and practically relevant. In doing so, the thesis contributes to both the academic understanding of SEO and its practical application in real-world web development.

1.1 Research Questions

The thesis is guided by the following research questions, each addressing a distinct aspect of SEO for web applications:

RQ1: “How to improve the visibility of a web application in Google Search results?”

This question aims to identify the key SEO strategies and techniques that can improve the visibility of web applications in Google Search results.

RQ2: “How to utilize programmatic SEO to improve visibility of a web application in Google Search results?”

Focusing on the practical application of pSEO, this question is particularly significant due to the limited academic literature addressing pSEO’s specific techniques and applications.

RQ3: “How can SEO be implemented in a multi-locale application to improve visibility in Google Search results?”

This question explores how SEO strategies should be adjusted and what additional techniques should be employed when a web application supports multiple locales.

RQ4: “How can SEO performance of a web application be measured using Google’s tools, and how can these measurements be used to improve SEO in a deployed application?”

This question aims to explore how to measure and track SEO performance after deployment, specifically focusing on Google’s tools, and how this data can be used to refine and improve SEO.

1.2 Methodology Overview

The research adopts a mixed-methods approach. An extensive literature review is first conducted to explore established SEO practices for web applications. This is followed by a qualitative content analysis performed to define pSEO and identify practical implementation techniques based on expert-authored online sources. This approach is suitable given the limited availability of peer-reviewed research on pSEO. Finally, a case study is conducted using the firewood marketplace app to apply and evaluate the identified SEO techniques. This case study includes the hands-on implementation of various SEO techniques, demonstrates how SEO can be measured, and provides a practical example of how to conduct pSEO.

1.3 Use of Artificial Intelligence (AI)

Generative AI, specifically ChatGPT, was utilized during the research and writing process to assist in summarizing lengthy texts and to improve language. However, AI-generated content was thoroughly reviewed, edited, and validated by the author to ensure its accuracy, relevance, and alignment with the research objectives.

1.4 Structure of the Thesis

The thesis is organized into nine chapters. Chapter 2 introduces the technical background of web applications, including their architectures and rendering approaches and the specifics of multi-locale applications. Chapter 3 provides an overview of search engines, with a focus on Google Search. Chapter 4 explains the fundamentals of SEO and its relevance to web applications. Chapter 5 presents the literature review on SEO practices. Chapter 6 includes the qualitative content analysis on pSEO, defining it and structuring a practical framework for conducting it. Chapter 7 presents the case study of the firewood marketplace app. Chapter 8 discusses the findings, challenges, and implications, and provides answers to the research questions. Finally, chapter 9 concludes the thesis.

2 Web Applications

Before exploring the techniques to optimize web applications for search engines, it is important to understand the foundational concepts related to web applications, including the technologies that power them, how they are hosted and served to browser clients, and the underlying architectures. This chapter provides an overview of the basics of web applications, delving into their core components, and the principles behind multi-locale applications. While the scope of web applications is broad, the emphasis in this chapter is placed on the aspects most relevant to SEO, as this foundational knowledge is essential for understanding the broader context of this thesis.

2.1 Web Technologies

Web applications have become a fundamental part of modern computing by providing versatile tools for communication, shopping, entertainment, and more. A web application is defined as a computer program hosted on a remote server and accessed by users via a web browser [1], [2]. Technically, web applications operate on a server and are accessed by users through a client, typically a web browser. If a web application only delivers static content without any interactivity, it is called a website. Web applications that respond with raw data such as text or JSON (JavaScript Object Notation), are called web services. [2]

Unlike traditional software that must be installed on individual devices, web applications operate through browsers, making them compatible with most standard devices and operating systems. This approach reduces the burden on local storage and allows users to access the application from nearly any device with an internet connection. Furthermore, web applications enable multiple users to interact with the same program simultaneously, which is ideal for collaborative tasks. [1]

2.1.1 Foundational Technologies

The structure, appearance, and behavior of web applications rely on three foundational technologies: HTML, CSS, and JavaScript. HTML (HyperText Markup Language) defines the structure and organization of content displayed on web pages. HTML uses markup tags such as <p> for paragraphs or <img> for images, annotating text and other elements, which instructs browsers on how to display them. [3] Additionally, there are meta tags such as <title> and <meta> that can be used to provide information about the page for search engines

[4]. The markup tags consist of an element name, which is surrounded by < and >. Hypertext or links is one of the fundamental features of HTML. Links enable navigation between web pages and websites, creating the interconnected structure of the World Wide Web. HTML also incorporates semantic elements, such as <header> and <footer>, improving the accessibility and clarity of web content. [3]

CSS (Cascading Style Sheets) defines the visual presentation of web pages, including layout, colors, fonts, and spacing. CSS is standardized across web browsers according to World Wide Web Consortium (W3C) specifications. CSS enables development of responsive web applications that seamlessly adapt to different screen sizes and device types. [5]

JavaScript is a lightweight, interpreted, or just-in-time compiled cross-platform and object-oriented programming language designed to bring interactivity to web applications [6], [7]. It is widely used for tasks like animations, form validation, and dynamic updates to webpage content without reloading the page [6]. On the client side, JavaScript interacts with the Document Object Model (DOM) to manipulate webpage structure and behavior in real time, such as handling user inputs and events [7]. Modern JavaScript frameworks like React, Angular, and Vue.js streamline the development of dynamic, scalable web applications by providing tools for component-based architecture, routing, and state management [8]. Additionally, JavaScript extends beyond the browser through server-side environments like Node.js, enabling its use for backend services as well [7].

In addition to the three foundational technologies, web applications contain static files, such as images, fonts, videos, and other resources, which enhance the functionality and appearance of web applications [9]. These files can be hosted on the application server or delivered via Content Delivery Networks (CDNs). CDNs distribute copies of static assets across multiple servers worldwide, allowing faster delivery and reducing latency for users based on their geographic location. Using a CDN also reduces the load on the main server and improves overall performance. [10]

2.1.2 Interaction Between the Browser and the Server

The interaction between a browser and a server forms the foundation of web functionality. A client refers to any device connected to the internet, such as a personal computer or smartphone, equipped with web-accessing software, usually a browser, such as Firefox or Chrome. On the other hand, a server is a specialized computer responsible for storing and

delivering websites, web applications, and other content. When a client initiates a request to access a webpage, the server responds by delivering a copy of the requested content to the client's browser for display. This process enables seamless access to resources across the web. [11]

Communication between the client and server relies on the Hypertext Transfer Protocol (HTTP), which regulates the transmission of data. HTTP is a request-response protocol where the browser sends requests to the server, and the server responds with the requested resources, such as HTML, CSS, and JavaScript files, or media assets like images and videos. HTTP can also be utilized in other communication scenarios, such as from server to another server. Hypertext Transfer Protocol Secure (HTTPS), a secure version of HTTP, encrypts these communications to ensure data integrity and confidentiality. The process of handling requests and responses is central to how browsers fetch and display web pages, forming the backbone of modern web interaction. [12]

When a user enters a web address into their browser, the browser first contacts a Domain Name System (DNS) server to translate the domain name into the server's actual Internet Protocol (IP) address. Once the server is identified, the browser sends an HTTP request asking for the webpage's resources. If the server approves the request, it replies with a "200 OK" status code and begins transmitting the requested files in smaller chunks known as data packets. The browser then reconstructs these packets into a complete webpage, rendering the content for the user. [11]

As the webpage loads, the browser executes a sequence of steps to assemble and display the requested document. Initially, the browser parses the HTML file, which may contain references to external resources like CSS stylesheets and JavaScript files. It fetches these resources from the server as required and then parses and processes them. [11] From the HTML, the browser generates a DOM tree, while CSS rules are used to create the CSSOM tree (CSS Object Model) [9], [11]. JavaScript is then parsed, compiled, and executed to add interactivity or dynamic functionality [9]. Together, the DOM and CSSOM trees are combined into a render tree, which specifies how elements should be displayed visually [9], [11]. The browser calculates the layout of these elements and then paints them onto the screen, making the content interactable and visible to the user [11].

2.2 Web Application Architectures

The first website created at CERN in 1990 consisted of a collection of static HTML documents. Over time, the Web evolved from a medium for hosting simple, static content to a platform capable of executing complex applications. This was driven by advances in web technologies and the increasing demand for more interactive and dynamic user experiences. [13] Early web applications followed a simple request-response model where the client sent requests to the server, which then executed tasks such as querying a database and returned static HTML pages to the client. This model provided limited interactivity and required the server to send an entirely new page with each user action. [1]

In 1995, Netscape Communications Corp. introduced JavaScript, enabling client-side interactivity by allowing developers to show or hide elements and validate user inputs without server involvement. The introduction of Macromedia Flash, a plug-in multimedia player, in 1996 further enhanced web interactivity by enabling animations and multimedia features without requiring constant communication. In 1999, Java programming language formally recognized the concept of web applications. However, modern levels of interactivity were not achieved until the introduction of AJAX (Asynchronous JavaScript and XML) in 2005, which allowed developers to decouple data exchange from presentation logic. This approach eliminated the need for constant page reloads and significantly improved user experience. [1]

The release of HTML5 in 2008, along with its subsequent iterations, further advanced web application capabilities by providing developers with APIs for better performance and inter-software communication. These advancements reduced development complexity and improved browser functionality, leading to the widespread development of complex web applications, including e-commerce platforms, social networks, and mobile services. [1]

Selecting the appropriate web application architecture is critical for ensuring scalability, performance, and a seamless user experience. It also directly impacts SEO outcomes. The architecture dictates how applications handle data, interact with users, and scale under varying loads, making it a key consideration in modern web development.

2.2.1 Types of Web Application Architectures

There are two main types of web application architectures: Multi-Page Applications (MPA) and Single-Page Applications (SPA). The main difference between them is how they

transition between web application views. Multi-Page Applications rely on multiple HTML files that are dynamically generated by the server. Each interaction that requires a change in the page view triggers a request to fetch a new HTML file, which can introduce delays due to server response times and data transmission issues. [14] Despite this, MPAs offer several advantages, including ease of SEO optimization, simpler development requirements, and the availability of numerous prebuilt solutions [15]. These characteristics make MPAs well-suited for content-heavy applications that benefit from traditional page-based navigation and straightforward search engine indexing.

SPAs load a single HTML document and dynamically update its content through JavaScript APIs (Application Programming Interface), such as Fetch, without requiring full page reloads and loading new pages from the server. While SPAs deliver faster and more interactive user experiences than MPAs, they face challenges such as slower initial load times due to the need to fetch and execute JavaScript, and SEO difficulties caused by JavaScript-dependent content rendering. [14], [16] For a long time, Google bots ignored JavaScript-delivered content as search engines primarily relied on HTML for indexing and crawling web pages, but since 2014, Google's bots have been striving to understand JavaScript and Googlebot is constantly being updated [14].

SPAs are particularly advantageous for applications that require high interactivity and performance, such as dashboards and Progressive Web Applications (PWA) [14]. PWAs are web-based applications designed to provide an app-like experience, offering features such as offline functionality, push notifications, and the ability to be installed on a user's device [17]. SPAs allow parallel front-end and back-end development, thanks to their separation of concerns [15]. However, SPAs demand careful attention to state management, navigation, and performance monitoring. Frameworks such as React, Vue, and Angular are utilized to streamline development and solve these issues. [14], [15] The SPA concept emerged in the early 2000s with AJAX technology enabling asynchronous page updates. Over time, the rise of user experience considerations has popularized SPAs, supported by modern JavaScript libraries and frameworks. [14]

2.2.2 Rendering Approaches

There are two main approaches to rendering, Server-Side Rendering (SSR), and Client-Side Rendering (CSR) [18], [19]. Hybrid approaches combining both for optimal performance also exist. SSR involves generating HTML content on the server for each client request and

sending fully rendered pages to the browser. [14] This approach improves SEO and accessibility since the content is immediately visible to search engines and users, even in scenarios with limited JavaScript support or slow internet connections. SSR also enhances performance by prefetching all necessary data server-side, reducing the workload on the client-side. The distinction between SSR and CSR becomes particularly relevant for dynamic content, where the server generates HTML on-the-fly to meet the need for unique and timely responses. In such cases, it is impractical to pre-generate every possible page, and in SSR, the server delivers near-complete HTML with JavaScript handling interactivity. [18]

CSR is the traditional rendering approach in SPAs [14]. In CSR, the browser fetches an initial HTML file and associated JavaScript assets, which then dynamically render content on the client side. While CSR provides a more interactive user experience by enabling seamless route transitions, it suffers from slower initial load times and increased demands on client-side resources [14], [19]. For dynamic content, CSR relies heavily on JavaScript to fetch and display the content, making it ideal for highly interactive applications where the initial HTML serves as a lightweight container and most content is generated dynamically on the client [18].

Hybrid approaches, such as Isomorphic JavaScript, combine SSR and CSR to deliver optimal performance and user experience [14], [18]. Isomorphic JavaScript, also referred to as universal JavaScript, allows the same code to be executed on both the server and the client. This approach utilizes SSR for the initial page load and CSR for subsequent interface updates. [14] Generating static HTML on the server with SSR for the initial load ensures faster rendering and better SEO, while utilizing CSR for the subsequent interactions improves reactivity and user experience. For instance, the server might generate a skeletal structure of the page containing essential meta tags and placeholders, leaving JavaScript to fetch additional content or execute updates as needed, ensuring both rapid page rendering and efficient handling of dynamic user interactions. [14], [19] Modern frameworks such as React, Vue, and Svelte can be utilized to build SPAs with SSR capabilities [19].

Pre-rendering is another important concept in optimizing the initial page load for search engine efficiency and load speed [14]. Static Site Generation (SSG) is a pre-rendering technique used to create static websites by generating HTML, CSS, and JavaScript files ahead of time during the build process. These files are served to users as-is, without requiring server-side logic at runtime. A static website ensures that for any given URL, all users receive identical content, making it highly predictable and reliable. This approach leverages Static

Site Generators (SSG), software designed to compile content written in formats such as Markdown, HTML, or React into optimized static files. These static files can be served via CDN, ensuring fast delivery, improved scalability, and enhanced security. Unlike SSR or CSR, SSG eliminates server-side logic at runtime, making it an excellent choice for applications where the content does not require frequent updates or user-specific customization, such as blogs, documentation sites, and marketing pages. [20] SSG is particularly advantageous for SEO, as search engines can easily crawl the pre-rendered content [14].

Advanced pre-rendering methods extend the capabilities of traditional SSG to accommodate applications requiring dynamic or frequently updated content [14]. Incremental Static Regeneration (ISR) enables frameworks like Next.js to regenerate static pages at defined intervals or on-demand after deployment without rebuilding the entire site [21]. This ensures content freshness while retaining the performance benefits of pre-rendering. Similarly, Deferred Static Generation (DSG), used in frameworks such as Gatsby, delays the generation of certain pages until they are specifically requested by users. This approach reduces build times for large sites while providing flexibility for on-demand updates. [14] Combining static pre-rendering with dynamic update techniques like ISR and DSG offers developers a flexible and powerful approach to balance performance, scalability, and content freshness for web applications.

2.3 Multi-Locale Applications

Multi-locale applications, or internationalized applications, are applications that support multiple locales by adapting to different linguistic and cultural contexts. This adaptation presents several challenges that need to be considered in the design of the web application. For instance, the translated versions of text can have significantly different lengths and heights, leading to potential distortions in the page's layout, so called Internationalization Presentation Failures (IPF) [22]. Other challenges related to supporting multiple locales include the performance impacts from loading multiple locales, difficulties in testing, and maintenance of translations.

2.3.1 Internationalization and Localization

Internationalization (i18n) refers to designing applications in a way that facilitates adaptation to different languages and cultural conventions without requiring structural changes [23]. It

involves addressing foundational challenges, such as handling different text formats and layouts, to make localization easier as the development progresses. This approach focuses on quality and minimization of costs associated with adapting software to new markets. [24] Proper internationalization is essential for effective localization, which involves tailoring the product linguistically and culturally for a specific audience. Localization (l10n) includes translating content, modifying design elements, and ensuring region-specific compatibility in terms of symbols, units, and cultural expectations. [23]

The W3C thoroughly defines areas that need to be considered when internationalizing and localizing an application [24]:

- Universal Code Base: Ensuring applications support text in any writing system through Unicode across HTML, databases, and content management systems. Seamless text translation and metadata integration should be enabled to manage fonts, typographic styles, and bidirectional text.

- Text Direction: Most languages are read from left to right (LTR), but some languages such as Arabic and Hebrew are read from right to left (RTL), which affects layout design, tables, and UI components. For instance, to support both RTL and LTR languages, instead of using values such as “left” and “right”, alternatives such as “start” and “end” should be preferred, to ensure proper mirroring when changing language directions.

- Names, Addresses, and Formatting: Handling names and addresses varies significantly across cultures. For instance, some cultures use a single name, others multiple names, and the way the names are ordered differs between cultures. Therefore, the applications need to account for these linguistic differences both in the UI and in the back end.

- Time Zones, Currencies, and Dates: To provide seamless user experience, applications should standardize internal data formats while displaying information in user-friendly ways. Variations in decimal separators, date formats, and calendar systems must be addressed. Monetization strategies also need to consider currency exchange, local purchasing power, and regional pricing structures.

- Cultural Norms and Expectations: Cultural adaptation extends beyond language. For example, a check mark indicating correctness in some countries may signify an error

in Japan, which makes localization adjustments important. Visual elements, symbols, and monetization methods should align with local preferences, including credit card availability and mobile payment adoption. Local regulations and legal requirements also impact localization efforts.

2.3.2 Best Practices for Multi-Locale Applications

A key strategy for internationalization is separating text from development code, which allows easier translation and adaptation [23]. One approach is modularizing language-specific content into external resource files, enabling dynamic language loading based on user preferences. An alternative method is using automated translation plugins, which can rapidly scale language support, but does not guarantee UI integrity, requiring manual verification or automated testing to identify potential IPFs. [22]

Additionally, the developers and designers of web applications should avoid hard-coded assumptions about text order, punctuation, or styling to prevent IPFs when the content is localized. Maintaining a clear separation between markup (HTML) and styling (CSS) helps create flexible, adaptive designs that work across multiple locales. [24]

Various tools and libraries have been developed for different web application frameworks to facilitate internationalization and localization. For instance, next-intl is an internationalization library for the popular React framework Next.js, which helps developers efficiently manage translations for text content and URLs, and localize dates, times, and numbers [25]. By implementing robust internationalization strategies, applications can enhance their global reach and improve SEO by delivering content tailored to diverse linguistic and cultural audiences.

3 Search Engines

To discuss SEO, it is necessary to understand the concept of a search engine and how search engines work under the hood to deliver relevant search results for users based on their queries. This chapter provides the required information about search engines to be able to understand this thesis.

3.1 Understanding Search Engines and Their Functioning

A search engine is a software tool designed to collect, organize, and analyze data related to website content in order to provide relevant responses to user queries [26], [27]. This involves gathering data such as website URLs, keywords, structure, and links. Search engines store this information into a database, usually referred to as the search engine index, to evaluate the relevance and quality of web pages, ensuring they are matched effectively to user queries. [26] Once a website is indexed in the database, it becomes eligible to appear in search results, helping users navigate the vast online content. The information retrieval process through which search engines retrieve and present information from the web can be divided into several essential stages, each crucial for providing accurate and relevant results to users. [27] These stages include crawling, indexing, and ranking, which work in a sequence to identify, process, and organize information that users request [27], [28].

Crawling

The first step in the process is crawling, where search engines deploy automated programs, often referred to as bots, spiders, or crawlers, to discover and retrieve new or updated web pages [28]. These crawlers follow links and sitemaps to collect content and revisit websites to track changes [27], [28]. The number of pages crawled depends on the website's size and authority, and this data is processed and stored in the search engine's index [28]. In general, search engine crawlers examine the index page of a website unless they find updated content that requires re-crawling [27]. Crawling is a vital part of gathering data from the vast number of websites present on the internet [29].

Indexing

After crawling, the gathered data is analyzed and organized into the search engine's index [26]. This process involves categorizing web pages based on their content, metadata, structure, and relevance to potential queries [28], with the data being organized based on the

likelihood that it will answer a user's query [29]. The search engine index serves as a vast database of information that can be quickly retrieved when users perform searches [26].

Ranking

When a user enters a search query, the search engine evaluates its index to find the most relevant results. Factors such as keywords, content quality, backlinks, and user experience influence ranking. [27] Pages that are deemed the most relevant based on these factors are then ranked and presented in order of importance in the search results [29].

Through this complex process of crawling, indexing, and ranking, search engines ensure that users receive the most relevant and high-quality results for their queries. Each stage plays a critical role in optimizing the search engine's ability to deliver accurate, timely, and useful information.

3.2 Google Search

The currently most popular search engine, Google Search, was launched in 1997 and has evolved significantly over the years. Initially, its success was driven by the PageRank algorithm, which revolutionized search ranking by evaluating web pages based on the number and quality of links pointing to them, instead of relying solely on keyword frequency. [30] This approach, combined with faster, more relevant search results, quickly made Google the preferred search engine, surpassing competitors in popularity. Unlike other search engines of the time, which embedded search functionality within web portals, Google maintained a minimalist interface, further distinguishing itself from competitors. [31]

By the early 2000s, Google expanded its search capabilities beyond simple web pages. Google Images (2001), Google News (2002), and Google Scholar (2004) introduced specialized search functions enabling users to find images, news articles, and academic papers more efficiently [30]. Over time, Google has enhanced its ranking system by incorporating hundreds of additional ranking signals, improving search accuracy and relevance [31]. A major shift occurred in 2012 with the introduction of the Knowledge Graph, which enabled Google to provide direct answers to user queries by understanding relationships between entities such as people, places, and things. This marked a transition toward semantic search, moving beyond keyword matching to interpreting the intent behind searches. The Hummingbird algorithm, launched in 2013, further enhanced this capability by improving

Google's ability to process complex queries and deliver more contextually relevant results. [30]

Google has maintained a market share of over 90% since the early 2000, and in January 2025, it was reported to be at 89.79% [32]. Therefore, it is the most popular search engine by a huge margin, making the competitors nearly irrelevant when studying search engine optimization techniques. However, in the recent years, the rise of AI-driven chatbots has posed new challenges to traditional search engines. These AI technologies provide direct, conversational responses to queries, potentially reducing reliance on standard search results. Google has responded by actively integrating AI into its own search functionalities to maintain its dominance in the market. [30]

Google's search process follows the standard crawling, indexing, and ranking framework, but is enhanced by advanced technologies. Googlebot efficiently discovers and updates pages, while AI-driven indexing interprets content beyond just keywords, incorporating structured data and multimedia. Ranking factors include relevance, content quality, and user intent, with advanced algorithms like RankBrain and BERT improving natural language understanding. [33]

To further improve search result quality and relevance, Google implements significant, broad changes to its search algorithms and systems several times a year through core updates. These updates can cause noticeable ranking shifts as Google reassesses content based on factors like expertise, quality, and user experience. Websites negatively affected are not penalized but may need to enhance their content to align with Google's evolving standards. Google advises focusing on helpful, high-quality content to maintain or improve rankings during core updates. [34]

4 Search Engine Optimization

Search Engine Optimization (SEO) is a broad field, and a clear understanding of its key concepts is essential for this thesis. This chapter introduces and explains the most important SEO concepts and terms, while also providing a clear understanding of why SEO is conducted and why it is important.

4.1 Defining Search Engine Optimization

SEO is a systematic process aimed at enhancing a website's visibility and ranking within search engine results pages (SERPs). It involves employing various strategies and methodologies to increase organic traffic by improving a website's position in search results and making it more accessible to relevant users. [28], [35], [36], [37] SEO focuses on optimizing several elements of a website, such as keywords, titles, headings, meta tags, links, images, and website architecture, to ensure alignment with search engine algorithms [35], [37].

At its core, SEO encompasses both technical and content-based adjustments. It strives to assist search engines in indexing relevant content while influencing their ranking results [36]. For instance, SEO involves acquiring reputable and relevant backlinks to boost a website's authority and reputation [35]. Additionally, it requires a continuous effort to adapt to evolving search engine algorithms, as search engines regularly update their methods to improve user experience [28], [37].

SEO is an ongoing process that typically spans months to yield noticeable results, with three to six months often required to achieve high rankings on SERPs [27], [29]. Achieving and maintaining top positions necessitates the generation of high-quality content that aligns with target consumers' requests, increasing referral links from authoritative sources, and maintaining a positive online reputation. Search engine algorithms take into account not only the website itself but also the associated brand or company, including any negative mentions that could affect rankings. [29]

Moreover, SEO forms a critical component of digital marketing, focusing on making a website easily accessible and visible to users through organic search results [38]. As part of broader search engine marketing (SEM), SEO complements other techniques like search engine advertising (SEA) to maximize visibility and user engagement.

4.2 Importance of SEO for Web Applications

Google Search responds to over 8.5 billion searches every day [39], which underscores the enormous potential for visibility and traffic through search engines. However, Google displays only ten search results per page, and even the ordering of the results affects the user behavior heavily: the first three results on Google get 54.4% of all clicks [40]. Ranking high in search results increases visibility, which improves website traffic, increases brand awareness, positively affects credibility and trust, attracts potential customers, and improves conversion rates [27], [28], [35]. Because of this, there is a lot of competition for these top search results rankings. This makes SEO extremely important.

SEO has two main goals: 1) to make the website rank high in the SERPs for specific keywords or phrases, and 2) to make the website attractive and useful for users. By effectively implementing SEO practices, these goals can be achieved. This not only makes the website visible to the users but also increases the chances of the users clicking the link to the website and interacting with the website, which increases conversion rates. [27], [28], [38]

Content moderation and fact checks can affect the SERP rankings. Based on a study by Koronska et al. [41], on average, fact-checks outperform the sources that they are addressing, and the fact-checks can appear higher on the search results despite having a lower or equal optimization score within a topic. However, Koronska et al. observed that the fact-checks still tend to rank below the so-called Golden Triangle of the top three results, which might indicate that these positions are reserved for other types of results. Therefore, regardless of content moderation and fact checks, it seems that at least the top three positions could be achieved through strong SEO efforts.

4.3 Ethical and Unethical SEO Practices

SEO techniques are commonly classified as either ethical white-hat SEO or unethical black-hat SEO. White-hat SEO follows search engine guidelines and aims to provide value to users, whereas black-hat SEO involves manipulative practices designed to deceive search engine algorithms. [42] Search engines, including Google, enforce strict guidelines and penalize unethical practices to maintain the integrity of search results [43].

White-hat SEO includes ethical methods that improve a website's search engine performance without violating search engine guidelines [27]. These techniques include providing high-

quality, relevant content, using proper keyword placement, ensuring mobile-friendliness and fast loading speeds, engaging in natural—not purchased—link building, and maintaining a user-friendly website structure and accessibility [42], [44]. Ethical SEO practices aim to enhance a website's visibility in search engine results while ensuring a positive user experience [27].

One of the main reasons for choosing unethical SEO services instead of ethical methods is the false promise of achieving high rankings and a large number of clicks in a short period. However, this expectation is unreasonable because SEO is a gradual process. Additionally, modern search engines personalize results based on user location and preferences, making it impossible to guarantee a number one ranking. Rankings alone are not an effective metric for overall website performance, as the ultimate goal is to attract customers rather than generate irrelevant traffic that leaves the page quickly. [42] Although it is possible to achieve high rankings quickly using black-hat SEO techniques, this approach often causes more harm than good in the long run, as search engines can detect and penalize such manipulative practices [42], [43].

Black-hat SEO refers to unethical techniques aimed at manipulating search engine algorithms [42], [44]. These practices include keyword stuffing, which is excessive insertion of keywords into a webpage's text without providing useful information, cloaking, which means showing different content to users and search engines, using hidden text, and creating doorway pages that redirect users to different sites [42]. Other common black-hat SEO practices involve duplicating content, engaging in link schemes such as purchasing backlinks or link farming, hijacking pages to redirect users to malicious sites, and engaging in bowling, which manipulates a competitor's search engine rankings by interfering with their inbound links [42], [44]. These techniques are considered unethical because they violate search engine guidelines and attempt to artificially boost rankings instead of prioritizing user experience [44].

The ethical implications of SEO practices are significant since search engines hold considerable power over internet browsing habits. Many users primarily rely on search engines to find information and tend to visit only the highly ranked pages [44]. Ethical SEO aligns with both user needs and search engine guidelines, ensuring sustainable and legitimate website growth while maintaining fairness in search engine results.

4.4 Local SEO

Local SEO refers to the process of optimizing a business's online presence to increase visibility in local search results, focusing on connecting businesses with nearby customers who search for products or services online [45]. Local SEO encompasses strategies such as optimizing websites for local search queries, creating and managing a Google My Business (GMB) Profile, handling online reviews, and ensuring consistent Name, Address and Phone Number (NAP) information across all online directories [35]. This approach is crucial for both physical businesses and those seeking to attract online traffic, as it drives leads and foot traffic by making businesses prominent in local search results and map listings. Google's algorithms can distinguish between general search queries and those with local intent, delivering results relevant to the user's vicinity. For instance, a search for "Chinese restaurants" returns nearby establishments instead of distant locations, even if they have superior SEO practices. [45]

4.5 SEO for Google

Google has its own documentation website for SEO, Google Search Central [46], which provides extensive guidelines to various stakeholders for optimizing a website for SEO. As an official resource, it serves as one of the most reliable references for understanding Google's best practices.

Google recommends a range of SEO techniques to help improve a website's visibility in search results while adhering to best practices. According to the Google SEO Starter Guide [47], effective SEO starts with high-quality, relevant content that aligns with user search intent. Proper use of keywords in page titles, headings, and meta descriptions helps Google understand page topics, while structured data enhances search result appearance. Google also emphasizes the importance of a well-organized site structure, internal linking, and mobile-friendly design to improve user experience. Additionally, technical SEO elements such as fast loading speeds, secure HTTPS connections, and proper indexing through sitemaps and robots.txt files play a crucial role. [47] Adhering to these best practices ensures that websites remain competitive in search rankings while providing users with valuable and accessible content. The techniques for optimizing SEO will be more thoroughly studied in chapter 5, where a systematic literature review is conducted to analyze scientific research.

To maintain fair search practices, Google has set in place spam policies, which aim to prevent manipulative, non-ethical, tactics that degrade search quality and user experience. These policies prohibit deceptive practices such as cloaking, keyword stuffing, hidden text, and link schemes designed to artificially boost rankings. Additionally, autogenerated or scraped content that provides little to no value to users is considered spam. Websites violating these guidelines may face penalties, including lower rankings or removal from search results. Google's combination of automated systems and manual reviews helps enforce these policies, ensuring that search results prioritize high-quality, relevant, and trustworthy content. [43] To maintain visibility in search, ethical SEO practices should be utilized with a focus on user-first content that is original, well-structured, and genuinely informative.

Google provides a free tool, Google Search Console, to help website owners track their search performance and optimize their sites for Google Search. Search Console offers valuable insights into indexing status, search traffic, and overall site performance, enabling identification and fixing of issues such as crawling errors, mobile usability problems, and structured data enhancements. Additionally, it provides detailed reports on search queries, allowing webmasters to analyze how users discover their content and make data-driven improvements. Search Console also alerts site owners about manual actions made by Google's inspectors to the site, security vulnerabilities, and indexing issues, ensuring compliance with Google's search policies and improving site visibility. [48]

Google frequently releases core updates, which can impact website rankings. As these updates refine search algorithms, rankings may fluctuate, requiring ongoing monitoring and adaptation. The documentation website provides instructions on how Search Console should be used to monitor traffic changes and diagnose potential ranking drops. Google maintains a list of core updates, which should be monitored so that SEO performance can be evaluated after each core update. [34] Google advises waiting for a few weeks to assess the impact of any optimizations and adjusting strategies accordingly, as the changes take time from a few hours to even several months to be reflected on Google's end [47]. SEO is an ongoing process, and businesses must continuously iterate their strategies to align with Google's evolving ranking criteria.

5 Literature Review on SEO Practices

In this chapter, a literature review is conducted to explore the findings from scientific literature on SEO practices and to address the research questions. The chapter begins with a description of the methodology used to find and filter relevant literature. This is followed by a synthesis of the key findings, which are analyzed in relation to the research objectives.

5.1 Methodology

A literature review was conducted to examine existing scientific research on SEO. The literature review aimed to find and analyze all relevant and sufficiently novel literature to answer all of the research questions. The methodology for this literature review is based on the systematic approach outlined by Kitchenham & Charters [49], with modifications to make it more suitable for this thesis. This review was conducted individually, following a more flexible approach. The search strategy and inclusion criteria were customized to align with the unique context and objectives of this thesis.

5.1.1 Inclusion Criteria

The literature included in this review must be relevant to the research. To ensure that only appropriate literature was selected, inclusion criteria were defined. These criteria guided the selection process, ensuring that irrelevant material was systematically excluded. The inclusion criteria were the following:

- There is information that is related to at least one of the research questions.
- There is a mention of Google, or it refers to search engines in general.
- The paper was published in 2024 or later.
- The literature piece needs to be scientific.
- The language needs to be English.

Only sources that address at least one of the research questions were included to guarantee that the literature review directly contributes to answering these questions. Following this criterion ensures that the selected literature adds value to the research. Because the research focused on Google Search, having a mention of Google in the literature helped exclude

literature that does not address Google Search and thus is not relevant to answering the research questions. However, as Google Search continues to be the dominant search engine, if a specific search engine is not mentioned, it is a sensible assumption that the research is relevant for Google Search.

Search engines are constantly updated. Therefore, the literature needs to be as recent as possible. Google makes significant and broad changes to their search algorithms and systems several times a year, as stated in the background chapter on search engines. Google documents these core updates online. Google states that most sites should not worry about these updates, and that they might not be noticeable. [34] Search Engine Journal also maintains a list of these updates, and states that most of these updates are small and unnoticeable. However, they list many updates that have significantly impacted the SERPs. [50] The latest core update at the time of writing is the August 2024 Core Update [51]. Therefore, to get perfectly valid information from the literature, one would need to limit the publication date to later than September 2024 so that there would be novel information about SEO for the latest search engine version. However, during the searches, it became evident that literature on programmatic SEO and SEO localization was very scarce. In these cases, I chose to also search for older papers. Surprisingly though, for these topics there were no relevant papers from 2024 or even at all.

The purpose of this literature review was to focus specifically on scientific literature, which is why this was set as an exclusion criterion. Literature was considered scientific if it had been published in a scholarly context. Some papers were not peer-reviewed; in such cases, their quality was evaluated more thoroughly before inclusion. Limiting the language to English was natural, as the field primarily uses English, the key terms are defined in English, and the thesis itself is written in English.

5.1.2 Search Process

To ensure that relevant literature is found, I used three search databases: Google Scholar, ScienceDirect, and Scopus. The search process was done the following way for all of the research questions:

1. Run the search query for each database such that publication year is set to 2024 onwards.

2. Evaluate the first forty results for each search against the inclusion criteria based on title and abstract.

3. For the included papers, read introduction and conclusion and skim through the rest of the paper to determine if they should be selected for further analysis.

It is important to build optimal search queries for each research question to find relevant literature. “Search engine optimization” is a relevant keyword for all of the research questions, and including its commonly used abbreviation, SEO, helps improve search results. I also tested adding more synonyms and related terms such as “search results”, “search ranking”, “search visibility”, and “indexing”, but they did not improve the results, so I chose to exclude them.

For the RQ1, “How to improve the visibility of a web application in Google Search results?", it is also useful to include words, such as “techniques”, “strategies”, “practices”, and “methods”, to get more relevant results. Including “Google” is useful as the interest is in Google Search specifically. The search query for RQ1 is the following:

> (SEO OR "search engine optimization") AND (techniques OR strategies OR practices OR methods) AND Google

The searches were conducted on October 29th, 2024. The search for Google Scholar yielded a very large number of results. Narrowing the search further would have excluded relevant articles from the results. Therefore, I chose to keep the search query as it is and inspect the first forty results when sorted by relevance. The number of query results and the number of papers included in the elimination process are visualized in Table 1.

Table 1. Elimination process for the RQ1 search query

Source	Query Results	After elimination by name and abstract	After elimination by full text	Chosen for Analysis
Google Scholar	29,600	12	10	12
ScienceDirect	476	1	0	
Scopus	4,139	6	2	

The specific focus of RQ2, “How to utilize programmatic SEO to improve Google Search results?”, is on the pSEO techniques. A near synonym for programmatic SEO would be “automated SEO”. At the time of doing these searches, the research question also attempted to

understand the role of user-provided data in the context of programmatic SEO, which is why terms related to user-provided dynamic data were also used in the query. However, the researcher later recognized that such an addition to the research question is irrelevant and removed it. The following search query was used:

> (programmatic OR automat* OR "user data" OR "dynamic data" OR UGC OR "user-generated content") AND (SEO OR "search engine optimization") AND Google

The searches were conducted on October 29th, 2024. For ScienceDirect, the wildcard was removed and replaced with “automated”, as the wildcard was not supported. Without year filtering, Scopus yielded only 21 results, so all of them were inspected to see if they could be included. Although the searches yielded hundreds of results, they were not relevant at all. Refining the query further did not help either. For example, directly searching “Programmatic SEO” resulted in only one paper, and it had exactly one mention of “programmatic SEO”, but did not discuss it any further. It was clear that pSEO is not visible at all in scientific literature. To find information on pSEO, other internet sources are searched and analyzed in chapter 6. The number of query results and the number of papers included in the elimination process are visualized in Table 2.

Table 2. Elimination process for the RQ2 search query

Source	Query Results	After Elimination by Name and Abstract	After Elimination by Full Text	Chosen for Analysis
Google Scholar	847	2	2	2
ScienceDirect	165	0	0	
Scopus	21	0	0	

RQ3, “How can SEO be implemented in a multi-locale application to improve visibility in Google Search results?”, examines SEO techniques in the context of localized and international applications, which is why localization and internationalization are included in the search. Adding “web” helps obtain more relevant results, and results in the following search query:

> (internationalization OR localization) AND (SEO OR "search engine optimization") AND web

The searches were conducted on October 30th, 2024. The number of relevant scientific literature for SEO localization was almost as low as the literature related to programmatic

SEO. Therefore, for this topic it is also important to study other available internet sources. This is done in chapter 5. The numbers of query results and the number of papers included in the elimination process are visualized in Table 3.

Table 3. Elimination process for the RQ3 search query

Source	Query Results	After Elimination by Name and Abstract	After Elimination by Full Text	Chosen for Analysis
Google Scholar	4,290	5	4	4
ScienceDirect	385	1	1	
Scopus	0	0	0	

The emphasis of RQ4, "How can SEO performance of a web application be measured using Google's tools, and how can these measurements be used to improve SEO in a deployed application?", is on the methods for tracking and measuring SEO effectiveness to facilitate improving SEO in production applications. To obtain relevant results, it is important to include terms like "metrics", "analysis", and "evaluation" in the search. Including the names of Google's specific tools further enhances the relevance of the search results. The search query for RQ4 is as follows:

> ("SEO performance" OR "SEO metrics" OR "SEO tracking" OR "SEO KPIs") AND ("Google Analytics" OR "Google Search Console" OR "Google")

The searches were conducted on October 30th, 2024. Table 4 shows the numbers of query results and the number of papers included in the elimination process.

Table 4. Elimination process for the RQ4 search query

Source	Query Results	After Elimination by Name and Abstract	After Elimination by Full Text	Chosen for Analysis
Google Scholar	124	20	18	18
ScienceDirect	0	0	0	
Scopus	0	0	0	

Most of the queries generated search results that might include information related to more than one of the research questions. Therefore, it is not useful to categorize the papers based on which research question related query was used to find them, and instead study the included

papers, and categorize the findings of the papers instead. The total number of papers included in the elimination process a shown in Table 5.

Table 5. Total number of papers included in the elimination process

Source	Query Results	After Elimination by Name and Abstract	After Elimination by Full Text	Chosen for Analysis
Google Scholar	34,861	39	29	31
ScienceDirect	1,026	2	1	
Scopus	4,160	6	4	

5.2 Literature Overview and Relevance

The included literature is described in Table 6 with short descriptions of each paper's purpose, relevant methodology and key findings for this thesis, and themes with keywords and relevant research questions. Following the literature synthesis in Table 6, Table 7 highlights the number of relevant papers identified for each research question. There is plenty of existing research and literature for RQ1 and RQ4. However, there is less literature available for RQ3, and RQ2 clearly shows a significant research gap, as shown in Table 7. For RQ2, there is only one relevant paper [52], and even that paper does not mention the term programmatic SEO.

Table 6. Synthesis of the literature with short description of each literature piece

R.	Purpose	Relevant Methodology	Relevant Key Findings	Themes
[27]	Guide for improving SEO strategies for website owners and online marketers	Review, Industry Reports	Improving visibility through keyword optimization, valuable content, technical SEO, and regional search targeting.	RQ1: On-page, Technical, Off-page SEO RQ3: Local SEO RQ4: Monitoring and Analytics
[35]	Digital marketing textbook for postgraduate students	Textbook, Case Studies	Comprehensive SEO techniques: on-page optimization, link building, local SEO, keyword research.	RQ1: On-page, Off-page, Technical SEO RQ3: Local SEO RQ4: Monitoring
[28]	Importance of SEO for web applications	Review, Industry Reports	A comprehensive SEO strategy with technical optimization, quality content, and performance monitoring enhances rankings and visibility.	RQ1: SEO strategy, On-page, Technical SEO RQ3: Google My Business RQ4: Monitoring and Measuring

R.	Purpose	Relevant Methodology	Relevant Key Findings	Themes
[53]	Categorizing SEO factors into a framework	Literature Review, Meta-Analysis	SEO factors categorized into on-page, off-page, technical, UX, content, and local SEO.	RQ1: On-page, Off-page SEO RQ3: Local SEO
[54]	Evaluating SEO strategy effectiveness	Literature Review, Expert Survey	Keywords, technical SEO, and off-page SEO all significantly enhance rankings, with technical SEO being crucial for first-page placement.	RQ1: SEO strategy, On-page, Technical SEO, Off-page SEO
[55]	Improving e-commerce ranking through SEO	Design Science Research	SEO boosts website rankings but does not always increase traffic. Focus on content and technical optimization.	RQ1: On-page, Off-page SEO RQ4: Measuring, Ahrefs, Google Analytics
[56]	Impact of SEO on online shopper's purchase intentions	Literature Review, Causal-Comparative Design	SEO strategies, such as quality content and user-friendliness, improve rankings and increase purchase intent.	RQ1: On-page SEO, User Engagement
[57]	Developing SEO-optimized, user-centric web applications	Design Science Research	SEO strategies, including targeted keywords and technical architecture, improve rankings, organic traffic, and user engagement.	RQ1: On-page, Technical SEO, User Engagement RQ4: Monitoring, Tools
[58]	Improving website visibility and performance	Design Science Research	SEO improvements, such as optimized content, faster page loading, and responsive design, lead to higher rankings and visibility.	RQ1: On-page, Off-page, Technical SEO RQ4: Google PageSpeed Insights
[59]	Examining technical SEO's impact on performance	Review, Case Studies	Technical SEO factors, such as mobile optimization and code efficiency, improve load speed, user engagement, and SEO.	RQ1: Technical SEO, UX RQ4: Core Web Vitals
[60]	SEO and readability of diabetic retinopathy websites	Literature Review, Case Study	Websites with better readability scores rank higher in search results.	RQ1: On-page SEO RQ4: Semrush
[61]	SEO characteristics of Moodle platforms in Central Asia	SEO Analysis with Tools	Improved page structure and external links lead to higher user engagement.	RQ1: On-page, Off-page SEO, User Engagement RQ4: SEO Metrics
[62]	High-quality content creation for SEO	Quantitative Research, 120-Day Experiment	Clear, concise content aligned with Google's preferences ranks higher and enhances user experience.	RQ1: On-page SEO, Content Optimization RQ4: Google SERP Rankings, Readability Tools

R.	Purpose	Relevant Methodology	Relevant Key Findings	Themes
[14]	Comparing SEO strategies for SPAs and MPAs.	Comparative Analysis, Implementation	Combining SSR with client-side updates improves SPA visibility.	RQ1: On-page, Technical SEO RQ4: Google PageSpeed Insights, Seobility
[29]	Synergy between contextual advertising and SEO	Structured Analysis	Combining SEO with contextual advertising increases targeted traffic and improves rankings.	RQ1: On-page, Off-page SEO RQ4: Web Analytics, Google Analytics, Behavioral Factors
[63]	Fundamentals of SEO and its impact on visibility	Literature Review, Industry Reports	SEO techniques: on-page (keywords), off-page (backlinks), technical SEO (site structure) enhance visibility.	RQ1: On-page, Technical SEO RQ4: Google Search Console
[64]	Evaluating localization on Samsung's website	Case Study, Qualitative Assessment	Localization prioritizes consistency and usability over cultural adaptation. Some decisions are influenced by SEO to maintain global uniformity.	RQ3: Localization, Multi-locale SEO
[52]	Video streaming platform using SEO	Design Science Research	SEO best practices and content optimization improve rankings, with language and geographical factors influencing SEO	RQ1: On-page SEO RQ2: Programmatic Creation of SEO Pages RQ3: Effect of Language on SEO RQ4: Measurement
[65]	Platform model for market expansion using SEO	Case Study	Localized websites increased visibility and engagement in target markets.	RQ1: On-page SEO RQ3: Multi-locale SEO, Localization RQ4: Google Analytics, Google Search Console
[45]	Developing a metric for local SEO	Empirical Research, Indicator Validation	Cumulative Indicator Score boosts visibility. Local SEO success is driven by Google My Business, reviews, and content relevance.	RQ1: On-page SEO RQ3: Local SEO RQ4: Google Analytics, CIS score
[66]	E-commerce website quality and SEO	Exploratory Analysis, SEO Audits	Meta descriptions, brand names in titles, and well-structured content improve rankings.	RQ1: On-page SEO, RQ4: SEO Audit Tools
[26]	Impact of SEO metrics on search engine ranking	Comparative Analysis with SEO Tools	Backlinks and optimized URLs significantly enhance web visibility.	RQ1: Off-page, Technical SEO RQ4: SEO Tools, Visibility Index

R.	Purpose	Relevant Methodology	Relevant Key Findings	Themes
[41]	Analyzing the effect of SEO on fact-checking content	Comparative Analysis of SERP Rankings	Fact-checks often rank higher due to Google's content moderation policies, regardless of SEO.	RQ1: Content Ranking Factors, Moderation RQ4: Measuring SEO Site Checkup
[67]	SEO, content marketing, and social media	Surveys, Interviews	SEO increased organic traffic by 40%, with tools such as Google Analytics tracking performance.	RQ1: On-page, Off-page SEO RQ4: Google Analytics, Semrush, Ahrefs
[68]	Impact of website consolidation on SEO	SEO Audits, Implementation, Feedback Collection	Eliminating redundant pages and optimizing site structure improves rankings and SEO.	RQ1: On-page SEO RQ4: CMS Tools
[69]	Proposing metrics for link quality	Conceptual Framework, Machine Learning	Trustworthiness, relevance, and domain authority are key metrics for evaluating link quality.	RQ1: Off-page SEO RQ4: Domain Authority, PageRank, Link Quality Metrics
[70]	Enhancing SEO through link analysis	Algorithmic Link Evaluation	External link quality plays a crucial role in SEO, with tools, such as Ahrefs, maximizing effectiveness.	RQ1: Off-page SEO RQ4: Link Analysis, Ahrefs, Majestic, LinkChecker Pro
[71]	Forecasting SEO traffic performance	Quantitative Analysis, SEO Data	Simple models for forecasting SEO performance are more practical than complex ones.	RQ4: Google Clicks, SEO Forecasting
[36]	Utilizing AI for SEO improvement	Literature Review	AI can significantly enhance SEO accuracy and improve search result relevance.	RQ1: AI-powered SEO
[38]	Using AI for visitor behavior and SEO	Case Study, AI Framework	AI-based SEO tools automate keyword optimization and enhance technical SEO.	RQ1: AI-driven SEO RQ4: Google Analytics, Monitoring, Brand Quality
[72]	Using LLMs for trend-driven SEO keyword generation	Experimentation, LLMs, Google Trends	Real-time keyword optimization and trend monitoring improve search visibility and accessibility.	RQ1: LLM-based SEO, keyword optimization

Table 7. Number of relevant papers for each research question

Research Question	Number of Relevant Papers
RQ1	29
RQ2	1
RQ3	8
RQ4	24

5.3 Findings from the Literature

The findings are categorized using the SEO mix 6 O's classification framework [53], which divides SEO into six categories: On-Page SEO, Off-Page SEO, Technical SEO, Optimized User Experience SEO, Online Content SEO, and Organic Local SEO. Additional categories have been added for AI in SEO, Measuring and Maintaining SEO, and Programmatic SEO. Additionally, the subcategories for these high-level categories do not match entirely with the used framework, as the material from the literature review included some techniques that were difficult to place within any of the categories presented by the framework. Many of these categories contain overlaps such that several techniques affect multiple other areas as well. For example, providing high-quality relevant content also improves the user experience [54], and designing mobile-first from the technical point of view is important for user experience on mobile devices [53].

5.3.1 On-Page SEO

The On-Page SEO factors category, as defined in the SEO mix 6 O's framework [53], includes techniques for optimizing individual web pages. It is a key component of the overall SEO strategy [27]. This category contains techniques related to keywords, title tag, meta tags, heading tags, domain, page URL, content, and image optimization [53]. Some papers also use term on-site SEO [38], but in general, the definition of on-page SEO is similar across the reviewed literature [26], [27], [28], [38], [57]. Some of the papers, such as Kumar & Ramasamy [35], also include user experience factors within the On-Page SEO category. This definition includes elements such as load speed, mobile compatibility, and the overall ease of browsing the page. Including user experience factors within the On-Page SEO category makes sense, because user experience can significantly differ between pages, and it is a feature of a page. However, in this thesis, the user experience factors have been separated into its own category, as defined by the framework. On-page SEO is important because it focuses on adherence to search engine guidelines and relevance of a page to specific keywords, which helps search engines recognize the relevance and quality of a page [27]. This helps the page achieve a higher search ranking, and gain more relevant organic traffic [26], [27], [28], [35].

Keyword Optimization

Keywords are specific words and phrases that users are likely to use in the search engine when looking for information, products or services [53]. These keywords are related to both

the content and the targeted users, and essentially connect users with the content they desire [53], [58]. Keyword optimization is the strategic process of selecting relevant keywords and placing them strategically within content, headings, URLs, and metadata to help search engines understand the website's focus and relevance [36]. By using these keywords in a smart and natural way, a website becomes more likely to appear in search results for specific searches, which increases its visibility and relevance to user queries [27]. Daoud et al. [54] found that strategic keyword optimization has a strong positive effect on website ranking and online visibility, and they state that keywords are a key element in improving a website's ranking within search engine results. Overall, the reviewed literature consistently emphasizes the importance of keywords for SEO.

Selection of the most effective keywords is crucial for the success of the keyword optimization effort [63]. Ibrahim & al. [37] argues that identification of the keywords is the most crucial task. To find and select the best possible keywords, keyword research and analysis should be conducted [58]. Keyword research and analysis aims to identify the key terms and phrases that users commonly search for when looking for the things that the website offers, such as products, services or information [28]. When a thorough and comprehensive keyword research is conducted, keywords can be integrated naturally so that they contribute to the coherence and value of the content [27]. Keyword research can help find search terms and phrases that the target audience uses to find content similar to the website being optimized [35].

Iankovets [29] suggests forming a semantic core, the set of keywords that represents the core topics, themes and content of a website. This semantic core can include tens of thousands of keywords depending on the type of the website and its information architecture. Query clustering should be applied to the selected keywords in the semantic core with the aim of identifying groups of keywords, clusters, within different thematic areas. This process can help form the semantic structure of the website, ensuring it aligns with the search engine algorithms and user intent.

There are several tools available that can be used to discover and identify impactful keywords and to analyze competitors. Tools used and recommended for keyword research in the reviewed literature include Semrush [29], [53], [35], [57], Ahrefs [35], [53], Google Trends [55], Google Keyword Planner [35], Neil Patel [55], Serpstat [29] and Moz Keyword Explorer [53]. These tools can be used for competitor analysis [29] and to provide insights

into search volumes, competition levels, and related keywords [53]. The information about competition levels and search volumes of keywords is useful because it enables discovering high-volume keywords with low competition [35], making it easier to select keywords that drive more traffic. Kumar & Ramasamy [35] recommend focusing on long-tail keywords consisting of multiple words and phrases that are specific to the website's niche and that carry commercial value.

The keywords should then be strategically integrated across the different parts of the website [54]. Keywords should be used in the page titles, meta tags, headings, URLs, domain, content, and internal links [28], [37], [38], [54], [55], [60]—essentially everywhere on the website where there is text that the search engine can interpret.

Page Title Tag

Title tag , often referred to as page title, is a HTML tag that is defined in the head section of a web page [73]. The page title defines the title of the web page, which is shown in the search results [29]. The key findings about title tag from the literature can be synthesized as follows: The page title should be defined for each page individually, containing the relevant keywords for each page. The length of the title should be somewhere between 40 and 65 characters long. To achieve this length, it is recommended to avoid stop words. Stop words are commonly used words in a language. In English, these words are for example "a", "the", "is", and "are". Page title is the first thing that is displayed when a browser analyzes a web page, so it is very important to have a brief and clear but attractive title for the user [58].

The page title should be defined correctly for each page, because the search engine uses it for scanning and indexing the page [29]. Each page should have a unique title that reflects its distinct content [53]. This ensures that the pages appear in search results for relevant queries.

It is recommended that the title is relevant to the content of the web page [29], and written in the language of the target group [53]. The title should include the main keyword or phrase related to the web page [58]. A common method is placing the most frequent search query at the beginning of the title [29]. It is also recommended to include the brand name in the title, for instance by adding it at the end of the title, separated by a delimiter, such as a vertical bar ("|"), to improve brand visibility in search results [66]. The importance of using keywords in the title is non-negligible: Gopalakrishna [28] refers to an article by Semrush stating that pages that contain a keyword in the title tag have as much as 45% higher click-through rate

than those that do not. Muñoz-Terol et al. [52] optimized existing title tags by deleting stop words. The goal of this process was to reduce the length of the title by deleting less meaningful words for information retrieval. Terol et al. argued that this way the title closer matches the search queries, where these stop words are often omitted. Therefore, deletion of stop words is a useful technique for keeping the title within optimal length limits and improving its relevance to search queries.

There are several differing recommendations for the length of the page title. Makrydakis [53] concludes that the most effective length with spaces included is 10-70 characters. Marrón et al. [58] refers to Google's recommendations stating that the title length should not exceed 70 characters. Iankovets [29] states that the optimal length would be 60-70 characters, but the maximum length could be up to 120 characters. Król et al. [66] refers to several sources in determining the optimal length: Screaming Frog SEO Spider tool recommends title length to be 30-65 characters long. Zadroweb SEO Auditor limits the length to be under 55 characters long to support all search engines. SEO Checker Tool recommends the length to be 55-66 characters. Król et al. also included an expert's opinion, the SEO leader at Whites, who recommends the length of 55-65 characters. The upper length limitation is to prevent the title from snapping in the search results. In general, the most common length recommendation seems to be 55-65 characters. The optimal upper limit defined by all of the sources is nearly identical, averaging 65 characters. The lowest recommendation for upper length limit of 55 characters is not relevant for Google Search, as it is accounting for other search engines. There are more differences in defining the shortest optimal length, as it ranges from 10 to 55 characters. On average, the recommended minimum length is 42 characters. It is also notable, that since the Google Search browser does not use a monospace font, the actual limit of the characters until the title gets cut is dependent on the characters used in the title: for example, "i" and "l" take significantly less space than "w" or "m".

Description Meta Tag

Description is a HTML meta tag defined in the head section of a web page. The description tag defines the description text of a page visible in the search results [29]. The key findings about the description tag include: The description should be individually written for each page, and it should describe the content of the page and include keywords. The use of stop words should be minimized. To grab the attention of users, emojis could be used in some contexts. The optimal length of the description tag is between 125-160 characters.

The description meta tag should be specified correctly for each page on the site [60] as the search engine uses it for scanning and indexing the page [29]. Because it is visible to users on the search results page, it is also important for the user experience. Gopalakrishna [28] refers to an article by Semrush stating the importance of metadata optimization for successful SEO. According to the Semrush article, pages that have the meta description tag get 5.8% more clicks compared to the ones without.

The content of the description should be clear, brief, contain keywords, and describe the web page in a few sentences [29], [53], [14]. Makrydakis [53] highlights, that techniques such as using keywords in quotations or copying from other similar webpages should be avoided. Muñoz-Terol et al. [52] recommend deleting stop words from the description the same way as from the title tag to improve relevance to the search queries. Muñoz-Terol et al. also used an interesting technique to grab user attention on the search results page: They added an aleatory emoji, such as red heart, sparkles, or a smiley, in the description. This helps highlight the search result from other results that do not apply this technique, which in turn directs users' attention to the page with the emoji in the description. Król et al. [66] refer to editors of a Polish SEO portal pozycjonowanie.pl who recommend also including a call to action in the description.

There are plenty of different recommendations for the length of the description. Makrydakis [53] refers to Moz and states that Google recommends the description length to be 160-180 characters, with the maximum of 300 characters. Iankovets [29] on the other hand proposes the optimal length of 120-135 characters and maximum length of 200 characters. Muñoz-Terol et al. [52] claim the upper limit to be 160 characters "as recommended by search engines". Król et al. [66] utilize multiple sources in an attempt to find the optimal description length: the editors of pozycjonowanie.pl recommend the length of 160 characters. Screaming Frog considers the optimal length to be 70-156 characters long. Zadroweb SEO Auditor defines the optimal length as 150-160 characters. SEO Checker Tool sets the upper length limit of 270 characters. The SEO leader at Whites states that the length should not exceed 160 characters. Król et al. notes that Google does not have any official or strict length limit for the description, but they highlight that an example description in Google's recommendations has 130 characters. Sait Kyzy & Ismailova [61] considered description lengths of 4208 pixels and 6657 pixels on websites errors. Some sources use pixels instead of pixels because the font affects how much space each character takes. With the approximation that one character takes 6 pixels in width, as done by Screaming Frog [66], this corresponds to around 701 and 1110

characters. These clearly exceed the limits defined by literature. The average upper limit for description length based on these results is 159 characters, so with sensible accuracy, 160 characters. The average lower limit for optimal description length is 125 characters. Therefore, the recommended description length based on the literature could be defined as 125-160 characters.

Keywords Meta Tag

Keywords meta tag is a HTML meta tag used in the head section to define keywords for a web page. The content of the tag is not displayed to the users. There are different views in the literature about the keywords meta tag and whether it should be used or not. Notably, the keywords tag was not mentioned at all in a large portion of the literature.

Iankovets [29] argues that the placement of the keywords tag has become optional since 2007, and that practitioners advice to remove the tag. According to these practitioners, algorithms might perceive the tag negatively as it could be dishonest promotion of the site with artificially created semantics, and this could negatively affect the search ranking. Makrydakis [53] also discusses how several search engines, including Google, have published that the keywords meta tag will not be taken into account when the algorithm ranks the webpages due to the tag being abused for keyword stuffing. Keyword stuffing in this case means embedding keywords to mislead the search engine to considering the page as relevant even when it is not.

Regardless, Makrydakis [53] recommends using the keywords tag with five to seven keywords, without language restrictions and even including misspellings. According to Makrydakis, carefully using the tag is useful even though the keywords tag does not affect ranking that much. Makrydakis argues that there are several search engines, and the keywords tag could be useful for other search engines than Google, such as Bing and Yahoo. Based on these arguments, it seems that the keywords meta tag should be omitted when optimizing SEO for Google.

Heading Tags and Semantic HTML

The HTML markup of the page, especially the heading tags are important for SEO. When the HTML document is structured well, and semantic markup is used, search engines can understand the content better, which improves search ranking and possibly makes the search engine display rich snippets from the page [28]. These semantic HTML elements include for example header, nav, main, article, and footer. The importance of utilizing the six heading

tags, <h1>, <h2>, <h3>, …, and <h6>, correctly for optimizing SEO is very clear as can be seen from the number of research papers highlighting it [28], [29], [53], [58], [60], [61].

When the heading tags are used to define web page sections [60], they create a clear structure for the content, which helps search engines in understanding the hierarchy and relevance of the information on the page [53]. The heading tags should be filled with relevant keywords to provide search engines additional information about the content of the web page [53].

The main heading, <h1>, is the most important heading tag for SEO as it indicates the main topic of the page [53]. Each web page should have exactly one main heading as having more than one main heading negatively affects the structure of the page [61]. The main heading should be placed in a visible location, usually to the top of the page [29]. The main heading can have more words than the page title to better explain the topic of the web page [58]. Marrón et al. considers it viable to have the main title contain the same text as the page title, although they recommend using more words, whereas Iankovets [29] recommends that the main title should not be the same as the page title. Iankovets recommends that the main title should be concise and contain the main search query. Iankovets also recommends avoiding the word “buy” and its synonyms in the heading tags.

The heading tags should be used logically, and in a hierarchical order based on the numberings of the tags, such that the main heading tag <h1> comes first, and the following tags <h2>, <h3>, etc. define headings for the subsections [53], [58]. This helps establish a clear content hierarchy [28]. When subheading tags are used, heading levels should not be skipped [61]. For example, an <h3> tag should not follow an <h1> tag unless an <h2> tag has been used in between. The subheadings should contain different text from the main heading [29]. The number of headings should also correspond to the volume of the text: the more headings are used, the more text the page is expected to have [61].

Domain name

Domain name is the unique name that identifies a website on the internet, such as “firewoodmarket.com”. There are only a few mentions of domain name in the reviewed literature. Makrydakis [53] recommends aligning the domain name with the brand name, as users typically search for the brand using that keyword. A brand-aligned domain improves recognition, trust, and credibility, while reinforcing the website’s relevance, which improves

search engine rankings. Makrydakis also states that consistency across the domain and other platforms strengthens the overall online identity.

Selection of the domain name could also be influenced by keyword research as proposed by Setiawan et al. [65]. This is especially relevant, when there is no brand name. In these cases, the keyword can align with the business activity, clearly communicating the website's subject to both users and search engines. This enhances visibility in relevant searches and is likely to improve click-through rates, as users tend to prefer domains that match their search queries [53].

Makrydakis [53] defines the ideal length for a domain name to be less than 15 characters, highlighting that search engines favor shorter domains. He further notes that shorter domains are easier to share on social media, which contributes to overall visibility. Additionally, Makrydakis suggests that using hyphens in domain names can help search engines recognize individual keywords. However, he also cautions that hyphens may reduce memorability, increase the risk of mistyping, and associate the domain with lower-quality sites. Based on these considerations, using hyphens in the domain name seems like a bad practice for SEO.

Page URLs

URLs are very important for SEO, as they are a gateway to the site [58]. There are several things to consider when optimizing an URL for SEO. Based on the literature, the optimal URLs for SEO have a logical structure, contain relevant keywords separated with dashes, and are normalized, short, and static.

The URL structure should be logical and mirror the information architecture of the site [28]. This makes it easier for search engine bots to navigate, crawl, and index pages, ensuring all relevant content is included in search results. A well-structured URL also reflects the hierarchical relationships between pages on the site. [53] Descriptive URLs are more user-friendly, as they help understand the purposes of the pages. The user-friendliness improves ranking, user experience, and click-through rates [53], [63]. Duplicate URLs should be removed as they cause confusion for search engines, negatively affecting search rankings [58].

The URLs should be descriptive and contain relevant keywords that reflect the page content [28]. The keywords in the URL path help search engines understand the page's content and improve its chances of ranking higher for those keywords, but keyword stuffing with terms

irrelevant to the page should be avoided [53]. Marrón et al. [58] recommend using the page title as the URL path [58]. The use of keywords is very important: Gopalakrishna [28] refers to an article by Semrush that states that URLs that contain a keyword have 45% higher click-through rate than URLs without keywords. It is recommended that the words in the URL path are separated with hyphens (“-“), as it improves the readability of the URL and the SEO performance [28], [14]. Using hyphens instead of underscores (“_”) is a good practice, because search engines consider hyphens as spaces, leading to words separated by hyphens being interpreted as different words [53].

The URL should be normalized to facilitate the crawling of the web page [58]. The normalization process includes conversion from uppercase to lowercase, removal of punctuation, removal of special characters and unusable query parameters, and removal of accents [58], [14]. Use of lowercase letters in URL avoids confusion [53]. The removal of accents is important so that the URL can be more easily used internationally. Removal of punctuation from the URL naturally also means removal of file extensions. [58] Additionally, the URL language should be in English or in the language of the page written with Latin characters, as browsers can not read some non-Latin characters [53]. Furthermore, the URL should not contain stop words, such as “of”, “with”, and “for” [14]. For example, Muñoz-Terol et al. [52] optimized their URLs to match the pattern ”https://domain.tld/keyword-terms-embedded-video” instead of “https://domain.tld/video-category/video-subcategory/keyword-termsembedded-video”, effectively removing the “video-category” and “video-subcategory” stop words.

It is best practice to keep the URLs short [28], [53], [58], [14]. Gopalakrishna [28] refers to a Semrush article that reports that URLs with 50-60 characters usually rank highest in search results. Makrydakis [53] on the other hand argues that the length of the URL does not have a significant impact on SEO ranking, but that long URLs can seem spam. Thus, Makrydakis recommends that the URL should contain fewer than 10 words, with 6 or 7 keywords considered optimal.

Dynamic URLs should be avoided for SEO, and static URLs should be used whenever possible. Dynamic URLs are useful for handling large amounts of content or personalization purposes, but they are not optimal for search engines which prefer static URLs [53]. Static URLs are easier for search engines to interpret and index. Static URLs are also beneficial for users, because simple static URLs are also easier for users to remember. [58]

Content and Keywords

The content should be relevant and contain appropriate keywords in a natural way. This helps search engines understand the relevance of the web page to user queries, improves indexing, and increases the probability of the page ranking higher in search results [28], [63]. Keywords should be consistently used in all elements of the webpage, including the alt texts of videos, images, and other multimedia elements, to make it easier for search engine bots to find them [55]. In addition to single-word keywords, keyword phrases and long tail keywords should be used. Long tail keywords are search phrases that contain over three words, which makes them more specific than generic terms, typically leading to a lower search volume [53]. Long tail keywords are useful in SEO because they have less competition, which allows ranking high in search results for specific niche audiences and queries. Primary keywords should also be supported with secondary keywords, to address a broader range of search queries. [53]

The content of a web page should contain enough words for the search engines to understand the content. Gopalakrishna [28] and Makrydakis [53] have differing opinions on how long the content should be for optimal SEO. Makrydakis recommends aiming for having at least 300 words on a page, but recommends keeping the articles still rather short, less than 800 words long, to prevent overloading users with information. Gopalakrishna on the other hand refers to a Semrush article, which states that long-form content containing over 3000 words gets 3.2 times more traffic, and 3.5 times more backlinks than shorter articles of 901 to 1200 words. So based on this Semrush article, longer content is beneficial for SEO. Backlinks are a very important SEO factor that is discussed thoroughly in the Off-Page SEO section. It can be concluded that having longer content is beneficial, at least when it is relevant and is of high quality.

The number of keywords on a page in relation to the number of total words is also important, and overuse of keywords can be harmful for SEO. Keyword density means proportion of a keyword’s occurrences to the total number of words in the webpage’s content [53]. Makrydakis [53] defines the ideal density for main keywords to be 3% - 7%, and for secondary keywords 1% - 2%. Makrydakis highlights the importance of avoiding overusing keywords, keyword stuffing, as it is harmful for user experience and SEO. According to Makrydakis, having a keyword density of 10% or more is considered keyword stuffing, which could lead to search engines blocking the website. Iankovets [29] recommends keeping the keyword density below 8% to avoid oversaturating the text with keywords, and refers to These keyword density recommendations seem unnatural, which might decrease the quality of

the content. For instance, in an 800-word content, having at least 3% density would require using the keyword at least 24 times. The density of 7% would require having as many as 56 occurrences. Therefore, the best practice is to ensure that the content includes several keywords naturally and meaningfully without disrupting the flow.

Word weight is another important metric. The weight of a word reflects its semantic relationship with the content of the page. The weight is higher when the main keyword is included in the page title, positioned in a header, emphasized in bold, placed within the first third of the text, or used in image captions. [29] Placing keywords at the beginning of the content and enhancing their weight is effective for SEO, as search engines prioritize the start of a page during crawling [53].

The closeness of keywords to each other in the content, keyword proximity, is also an important factor. Using keywords sequences without other words in between improves SEO [53]. Muñoz-Terol et al. [52] used this to the extreme in their project: As their web pages' main content was videos, they decided to remove all stop words from their text content of these video pages to make the user queries match better with searches, and essentially to improve keyword proximity. Iankovets [29] highlights that it is important to improve these quality indicators related to keyword density, weight and proximity for the site as a whole, in addition to individual pages.

Image optimization

To optimize images, focus should be put into the alt and title attributes, image captions, filename, file type, file size, and the way the image is loaded on the page. The alt attribute provides a textual description of an image for accessibility and SEO purposes, and the title attribute offers additional information when hovering over an image. The caption appears alongside the image as visible contextual information for users, but it requires additional HTML elements, <figure> and <figcaption>. [74] The alt and title attributes, image captions, and filename should all be descriptive and include relevant keywords [28], [35], [53], [58], [60], [14]. This improves accessibility and helps search engines understand the content of the images better [28], [35], [53], [58]. The title is shown when the image is hovered, and the alt tag is read by screen readers. The alt tag should briefly describe the image [58]. The caption appears below the image and briefly describes it [53].

It is slow to load large images, which directly slows down the load speed of the page. This negatively affects user experience and SEO [53]. Optimizing the size of the images is particularly important on mobile devices where bandwidth may be limited [28]. Reducing the file size of the images directly correlates with faster loading of the webpage also [53], which is why the literature recommends reducing the image sizes via compression and use of optimal file types. Gopalakrishna [28] recommends reducing the file size 50-80% such that the quality is not significantly reduced. Marrón et al. [58] refers to SEO experts who recommend reducing the quality of the image down to 80%, as long as the perceived quality remains high enough. This is unique for each image. Golopakrishna, Marrón et al., and Kowalczyk & Szandala recommend using WebP image format, as it can reduce the image size compared to JPEG or PNG file formats, while retaining the highest possible quality. Golopakrishna refers to an article by Ahrefs, stating that using WebP instead of JPEG or PNG can reduce the file size 25-35%. Makrydakis [53] does not note WebP and instead recommends using JPEG for product and business photos, and PNG for graphics. WebP appears to be a superior option compared to PNG or JPEG due to its smaller file size for the same perceived quality. Additionally, since WebP supports transparency, it can seamlessly replace PNG files that require this feature.

The dimensions of the images have a significant effect on the image size. By implementing a responsive image strategy, images with different resolution can be used based on the size of the screen [14]. This is especially beneficial for mobile devices, as they have smaller screens than desktops, and thus can usually be served with smaller images as well, thus reducing page load time. The images that are below the fold, so not visible when the page is first loaded, should be lazy loaded to improve the initial page load time [28]. However, the images that are visible above the fold, should be loaded with high priority so that the Largest Contentful Paint (LCP) metric is not negatively affected [14].

5.3.2 Off-Page SEO

The Off-Page SEO category defined by the framework focuses on external signals and influences that impact website's search engine rankings [53]. The term off-page SEO is consistently used in the literature to discuss about all the external factors and actions taken outside of the website that affect the credibility and ranking of the site [26], [28], [38], [53], [54]. In some contexts, it is referred to as external optimization [29]. Off-page SEO includes members who the developer of the site can not directly control [26]. The off-page SEO factors

include backlinks, social media, ads, influencers, mentions and citations in articles, sharing, blog posts, and reviews [26], [28], [29], [38]. Building high-quality backlinks seems to be the most important off-page SEO technique, as it has the most coverage in the literature. Daoud et al. [54] evaluated the effectiveness of various SEO strategies, including off-page SEO, in enhancing website ranking and online visibility. Their research shows that off-page SEO strategies significantly improve a website's ranking in search results. Daoud et al. particularly highlight the importance of high-quality backlinks.

Backlinks

Backlinks are links on a website that direct users to another website [26]. These links are considered backlinks of the site being linked to. Other terms used for backlink in the literature include inbound link, external link, and incoming link [26], [69], but "backlink" is the most commonly used term.

Search engines consider backlinks one of the most important factors when determining the search result rankings, with sites having more backlinks typically ranking higher [26], [36], [45], [61]. Backlinks help search engine bots discover and crawl websites more efficiently [26]. They are viewed as endorsements of a website's authority, trustworthiness, and relevance, which help build brand authority, improved referral traffic, and increased visibility across platforms [27], [35], [36], [38], [69]. In addition to the quantity of the backlinks, the quality of them is also a significant factor [27], [36], [38]. According to Dekate et al. [27] obtaining relevant and reputable links is crucial, because search engines value quality over quantity. Chanthati [38] supports this claim by similarly advising to pay more attention to the quality than the quantity of the links. Google's PageRank algorithm, which is part of the ranking system, evaluates a page's importance through the quality and quantity of its backlinks [69].

Ranking algorithms evaluate the authority of websites by analyzing the quality of their backlinks. This evaluation considers both the qualitative attributes of the links and the relevance of the linking site's content to the linked resource [29]. There are several known indicators for determining the quality of a backlink, focusing on determining the reliability, popularity, and visibility of the website hosting the backlink [69], [70]:

- Domain Rating and Domain Authority assess the overall authority of a domain based on the quality and quantity of backlinks.

- URL Rating focuses on the authority of individual pages.
- Referring Domains measures the number of unique domains linking to a site.
- Trust Flow focuses on link quality.
- Citation Flow evaluates link quantity.
- Organic Keywords track the number of search queries a site ranks for.
- Organic Traffic measures visits from free search queries.
- Total Number of Pages on a site can boost visibility by increasing the amount of indexable content.

Link building, or backlink profile development, refers to the process of acquiring high-quality backlinks from relevant, authoritative, and trustworthy websites [35], [38], [57]. A strong and diverse backlink profile with high-quality links boosts domain authority and search engine rankings [27], [28], [35], [52], [67]. Kumar & Ramasamy [35] and Asrigo & Kaburuan [55] recommend developing a link-building strategy or campaign. Kumar & Ramasamy recommend looking for opportunities for guest blogging, content partnerships, and collaborations with influencers, as they are effective strategies to acquire natural backlinks. They recommend focusing on the authoritative and relevant websites in the industry the website represents. Asrigo & Kaburuan also recommend utilizing blogs by both creating a company blog and finding external blogs where backlinks can be embedded within the blog posts. Creating a blog for acquiring backlinks seems like the easiest way to obtain backlinks. However, acquiring high-quality backlinks from authoritative and popular websites might be a lot more challenging.

Kumar & Ramasamy [35] recommend using diverse anchor texts for the backlinks in a natural way to avoid being penalized by search engines. According to Iankovets [29], the most optional ratio of anchor and non-anchor links is 20% to 80% for creating an organic link mass. Iankovets [29] states that links posted under reviews or recommendations on forums are considered the most natural backlinks. Iankovets also considers buying links from link exchanges and leasing temporarily published links as viable options for acquiring backlinks. Dekate et al. [27], and Daoud et al. [54] disagree with Iankovets, and recommend avoiding purchasing links, considering it harmful and potentially leading to penalties from search

engines. Given the risks associated with buying or leasing backlinks, along with their significant costs, it is advisable to avoid this practice.

Reviews and Testimonials

Customer reviews and testimonials influence user opinions and play a significant role especially in local SEO. Local SEO will be discussed further in chapter 5.3.6. Google's algorithms consider the average rating, quantity, recency, and distribution of reviews to assess how credible and relevant a business is [45]. Keywords within reviews can also enhance a business's visibility in search rankings for related queries [45]. Authentic reviews published organically are particularly valuable; in contrast, sudden spikes in reviews may indicate manipulation, reducing their impact on rankings [53]. Deceptive practices, such as using fake reviews and profiles, should be avoided, as they may offer short-term benefits but often result in penalties that harm both SEO performance and the business's reputation [45],[53]. Reviews also serve as social proof, enhancing online engagement and signaling value to search engines, which can further elevate a business's visibility in search results [53].

Social Media Signals

Social media can also be an important area for improving off-page SEO. Leveraging these platforms amplifies content, attracts more visitors and boosts brand recognition [35], [55], [57]. The interconnected nature of social media allows users to share website content, which creates valuable external links that contribute to a website's backlink profile, enhancing SEO performance [53]. Search engines interpret social signals, such as likes, shares, and interactions, as indicators of content relevance, popularity, and user engagement, which can positively influence rankings [36]. Moreover, social media encourages continued interaction and facilitates micro-community conversations, which enables users worldwide to interact with content, further extending its reach and impact [54]. These signals, often perceived as social proof, underscore the importance of social media mentions in shaping the perception of content and improving SEO outcomes [53].

5.3.3 Technical SEO

The framework defines the On-Site Technical SEO category as involving optimizations to the structure of the entire website infrastructure and its backend [53]. Technical SEO is discussed widely in the literature and considered to address all technical aspects of the website [27],

[35], [38]. Optimization of the technical features helps search engines effectively access, crawl, and index the content of the site [26], [27], [28], [35], which is essential for ranking higher in search results [28], [38]. Unlike in the framework, many sources include user experience related aspects within the category, such as ease of use and page load speeds [27], [28], [35], [38] which clearly are significantly affected by the technical features of the website. Technical SEO includes optimizing the architecture and structure of a website, ensuring mobile compatibility, utilizing special SEO-related files such as sitemaps, robots.txt, and schema markup, leveraging caching, fixing broken links and duplicate content, and implementing various other optimizations to improve crawlability, indexability, and page load speed [27], [28], [35], [38], [55]. It is also important to keep the system up-to-date with the latest security patches to avoid vulnerabilities that could damage the site's credibility and rankings [57]. Daoud et al. [54] evaluated the effectiveness of SEO strategies, and found that technical SEO practices have a strong positive effect on website ranking.

Architecture

Architecture is one of the most important factors affecting technical SEO. An SEO-friendly web architecture facilitates the crawling and indexing of content [57]. The two most common web application architectures are MPA and SPA. MPAs are generally easier to optimize for SEO than SPAs, due to the inherent challenges posed by the fundamental concept of a SPA. SPAs compared to MPAs have slower initial load times as the JavaScript in SPAs has to load content through network requests [14]. Code-splitting should be implemented to load only the necessary JavaScript for initial render [28]. Because SPAs have only a single HTML file, there are several challenges related to optimizing page titles and meta descriptions. To avoid duplicate titles and descriptions, which is a common SEO problem especially in SPAs, the title and description should be changed via JavaScript code. Each view should be treated as a URL with its unique page title and description. Another challenge with SPAs is handling of errors: by default, the server always returns status code 200 (OK), regardless of errors with statuses such as 404 (Not Found), 500 (Internal Error) occurring. To solve this problem, redirects should be added to URLs that return correct server status code, and a useful page for the user providing instructions on how to proceed. Error pages, such as 404, should be blocked from indexing by using the noindex meta tag rather than using the robots.txt file. [14]

It is essential for SEO success to ensure that the content is easily indexable by search engines, particularly for web applications that depend on JavaScript [28]. To prevent search engines

from missing critical content, care should be taken to ensure that important information is included in the initial HTML response instead of being dynamically loaded through JavaScript, as search engines may not wait for all JavaScript to load before indexing the page [28], [14]. SSR is a technique where the pages are rendered already on the server, which allows presenting fully formed pages to search engine bots, which improves indexing [57]. SSR and minimal JavaScript usage can significantly improve crawlability and initial page load times, which is why it should be utilized for critical content [28]. Some articles mention Hijax, an approach that enhances traditional MPAs using AJAX to enable SPA behavior while preserving SEO benefits. Although it was once considered a promising method for improving SEO in SPAs, Hijax is now largely obsolete and not widely adopted in modern web development [14]. One paper suggests utilizing “prerender” tag for pages that require a lot of JavaScript, to provide search engines with a static version of the content. [28]. However, according to MDN docs, the prerender tag is deprecated, and should not be used anymore [75].

Isomorphic JavaScript with prerendering is the most widely used approach to enhance SEO in SPAs, and these techniques are implemented by many popular frameworks. Isomorphic JavaScript refers to running the same JavaScript code in both the server and the browser, which enables prerendering pages in the server, and this way sending prerendered HTML to the browser for search engines to crawl. [14] Kowalczyk & Szandala [14] compared MPA (Flask), SPA (React) and Isomorphic JavaScript (Next.js) in terms of SEO, demonstrating that the SSG approach in Next.js positively impacts SEO. Kowalczyk & Szandala found that the application that visually behaves like a pure SPA, the Next.js version, managed to achieve the same SEO score as an MPA application, highlighting the SEO benefits of Isomorphic JavaScript.

Databases are also an important part of website architecture, and they can also impact SEO. Sahani et al. [57] discusses the importance of building a database schema that supports storing SEO-relevant data, such as content metadata, analytics, and user profiles. They also highlight the benefits of indexing and caching strategies to minimize page load times and speed up server responses.

Mobile-First Design and Accelerated Mobile Pages

Ensuring that the web pages work correctly on mobile devices is very important for the user experience, and for search engines, which is why it needs to be taken into account in technical

SEO as well. The user experience and accessibility aspects are discussed more thoroughly in the Optimized User Experience section 5.3.4. Mobile-first design approach is useful to ensure accessibility across various devices and to improve search rankings on mobile [57]. Gopalakrishna [28] highlights that Google predominantly uses the mobile version of web pages for indexing and ranking.

An open-source framework, Accelerated Mobile Pages (AMP), has been developed by Google to improve mobile web browsing speed by simplifying HTML, reducing resource usage, and prioritizing content delivery [59]. Gopalakrishna [28] recommends implementing these AMP pages for key content to improve mobile performance. AMP enhances SEO by boosting page load times and improves user engagement by reducing bounce rates. AMP pages also have the potential to appear in Google's "Top Stories" carousel, further increasing visibility However, the development and maintenance of AMP versions can be more complex due to its HTML and JavaScript limitations. [59]

HTTPS Protocol

The adoption of the HTTPS protocol, which utilizes Secure Sockets Layer (SSL) encryption, is crucial for both user security and SEO. HTTPS not only protects user data but also improves the trustworthiness of a website, which positively influences SEO rankings. Google recognizes SSL as a ranking signal, making its implementation an important factor in SEO. [57] Additionally, by automatically redirecting non-HTTPS requests to the secure format, websites improve their user experience while meeting search engine requirements for secure connections [14], [52].

Domain

The Top-Level Domain (TLD) and domain age play significant roles in SEO performance. The TLD, such as .com, .net, or .org, can influence trust and credibility, with certain TLDs associated with higher quality and more reliable websites, while others, such as .cc or .ws, may be linked to low-quality sites, negatively affecting rankings. Domain age is another important factor, as search engines tend to favor older domains, associating them with stability, credibility, and long-term commitment to quality content, which contributes to higher rankings. [53] Sait Kyzy & R. Ismailova [61] refer to an article by Seobility.net, stating that top-level domains are better for SEO than subdomains. A subdomain is part of a

main domain, appearing before the main domain name in a URL and separated by a dot, e.g., blog.example.com [76].

Internal Linking

Internal linking is important not only for enhancing user experience but also for SEO. A well-designed internal linking structure aids search engines in effectively crawling and indexing a website and improves user experience by guiding visitors to relevant content and encouraging further exploration of the site [35], [59]. This lengthens user visits and helps search engines understand the structure of the website and the relationships between its pages [59]. To optimize for search engine crawling, it is essential to ensure that the website has a clear and logical structure with internal links [28]. By carefully crafting these hyperlinks, the visibility and ranking of a website in search engine results can be significantly improved [63].

Anchor text is a critical component of link building and SEO, playing a significant role in how search engines and users interpret the context of linked pages. Each anchor link consists of two parts: anchor text and the underlying URL of the linked page. Anchor text is the clickable text. A properly crafted anchor text should accurately describe the content of the target page and seamlessly incorporate relevant keywords [29]. This approach not only helps search engines understand the relationship between pages but also improves user comprehension by providing clear expectations of what they will encounter upon clicking the link [28], [59].

Kowalczyk & T. Szandala [14] highlight that for optimal SEO results, anchor text must avoid generic phrases like “Learn more” or “Click here” and instead use descriptive and specific terms that align with the content of the target page. Informative and contextually relevant anchor text enhances the scalability of a website and ensures search engines perceive the links as high-quality and valuable [59], [70]. Furthermore, the use of exact-match keywords in anchor text should be approached with caution, as excessive use may trigger spam detection by Google’s algorithms [29].

The technical best practices for anchor text include ensuring links are embedded within the <a> tag with an href attribute that is parsable by search engine bots. Additionally, anchor text should be concise, not overly lengthy, and strategically placed to avoid overcrowding the webpage with multiple links clustered together. [14] Employing natural and varied linking strategies, including unanchored links whose text part does not reflect what the user will see

when following the link, such as brand names or domain URLs, can further enhance the perception of link authenticity and avoid penalization by search engines [29].

Muñoz-Terol et al. [52] employed an internal linking strategy for their video streaming meta platform, where anchor text for links is directly derived from the optimized page title of the target page. They also track their most visited pages and display links to them in the popularity order on the home page, while also displaying links to the top 15 requested URLs from the previous week in the page footers of individual pages.

Content shareability is also useful for driving traffic and improving SEO. Integrating social media sharing button and widgets into the web pages encourages users to share valuable content, which signals its relevance and popularity to search engines [59]. Social sharing not only increases visibility but also fosters user engagement across platforms [35]. While footer links are primarily used for internal navigation, incorporating external links sparingly and strategically can also enhance user experience and add value to the site [53], [14].

Dynamic values such as session identifiers should not be used in URLs as it weakens the ranking of a website by creating duplicate or non-canonical URLs that can confuse search engines. If such values are required in the URL, the website should be configured to prevent such indexing issues. [53]

Broken Links and Redirects

When content is moved within the website such that its URL changes, broken links are introduced. Gopalakrishna [28] highlights the importance of implementing 301 redirects when URLs are changed to preserve link equity and maintain search engine rankings. This ensures that both users and search engines are properly directed to the new URLs. Gopalakrishna refers to an article by Semrush, stating that failing to set up 301 redirects to changed URLs, leading to broken links, can cause up to 80% of the link equity accumulated over time to be lost. However, redirects should not be used to send users to pages they did not intend to visit. In such cases, automatic redirects without user consent can lead to a negative browsing experience and confuse visitors, which may result in diminished website rankings. Search engines may also consider these redirects unethical, further harming the site’s SEO performance. [53]

Duplicate Content and Canonicalization

Duplicate content issues can arise when multiple pages contain similar or identical content, leading to SEO complications. To avoid these issues, the “rel=canonical” tag should be used, particularly in cases of SPAs. This tag helps search engines recognize the preferred version of a page and prevents content duplication from negatively affecting search rankings. [28] Muñoz-Terol et al. [52] developed a video streaming meta platform containing pages similar to those on existing video streaming platforms. Therefore, they employed several on-page SEO best practices to reduce the likelihood that search engines would mistakenly identify these pages as duplicate versions of the source pages on the original platforms.

Language Metatag

The appropriate language metatag should be used in the HTML code of a webpage [14]. Specifying the language of the content helps search engines and screen readers understand the language of the content of the web page, leading to more accurate indexing and improved search results [53].

Robots.txt

The robots.txt is a text file hosted in the root of the website that provides directives to search engine bots about which parts of a site should be indexed and which should not [29]. For instance, the robots.txt file can be used to prevent crawling of unimportant pages such as “thank you” pages or expired product listings, thereby conserving crawling time and focusing the search engine’s resources on relevant pages [55], [14]. Regular updates to this file ensure optimal crawling behavior, especially in dynamic websites where content changes frequently [57]. By including a link to the sitemap in the robots.txt file, the bots can be guided to critical content efficiently. This linkage ensures that the most significant pages are indexed, helping search engines rank relevant content more effectively [29].

XML-sitemap

A sitemap is an XML file that outlines the structure of a website, enabling search engines to understand and navigate its content efficiently. This file provides metadata about each URL, including the frequency of updates and the priority of pages, allowing search engines like Google to prioritize crawling resources [29], [63]. For example, a sitemap is particularly useful for large websites with extensive archives or newly created sites lacking sufficient

backlinks [29]. By submitting the sitemap file to Google Search Console, it can be ensured that all pages defined in the sitemap are discoverable and updated for indexing [28], [55].

In addition to manually crafting the sitemap file, it can also be dynamically generated. Dynamic sitemap generation is especially beneficial for e-commerce sites and multimedia-heavy platforms, where the content changes frequently [29], [57]. This practice ensures that pages with videos, images, or news articles are included or excluded based on business needs. Consistent updates to the sitemap improve search engine visibility, helping the site achieve better rankings [55], [63].

Schema markup

Schema markup, in some context called structured data markup, is an SEO technique that involves embedding special markup into web page's HTML to help search engines better understand their content. By providing additional context, schema markup enables enhanced search result features such as rich snippets, which can boost visibility and improve user experience [28], [36]. Schema.org markup can be implemented for various content types such as articles, products, and events, offering search engines a deeper understanding of the webpage's purpose [28]. Gopalakrishna [28] refers to a Semrush article stating that pages with schema markup rank an average of four positions higher in search results, therefore schema markup is clearly a useful SEO technique.

5.3.4 Optimized User Experience

The Optimized User Experience category of the framework concentrates on elements that enhance the overall user experience [53]. User experience (UX) is defined as the overall impression people have when interacting with a product or service, particularly in digital contexts such as websites or applications, focusing on user engagement, retention, and the ease and enjoyment of use [27], [36], [57]. A positive UX ensures that visitors can easily navigate, understand, and engage with a website, which is essential for effective web design, customer retention, increased satisfaction, and the success of online platforms [27]. This SEO category is important, because search engine algorithms favor websites that offer great user experiences [59]. For instance, Google's RankBrain machine learning algorithm takes into account several metrics, such as Click-Through Rate (CTR), average time on page, and bounce rate, and all of these are positively influenced by good user experience [36].

The key user experience factors are intuitive navigation, responsive and mobile-friendly design, fast load times, and clean user interface (UI) elements. These factors directly contribute to both user satisfaction and improved SEO rankings. A well-optimized UX involves creating a mobile-friendly design, ensuring quick loading times, offering good navigation, and making content easily understandable [27], [57]. By prioritizing site speed, navigation, and content layout, websites can enhance user satisfaction and keep users around longer, which correlate with reduced bounce rates and increased interaction [54], [61]. For example, a properly structured navigation system, such as breadcrumb navigation, not only aids users in finding content efficiently but also improves indexing efficiently for search algorithms, thus boosting SEO performance [35], [58], [60]. Additionally, a clean and intuitive UI is crucial for retaining users and achieving better rankings, as poor UIs can lead to elevated bounce rates and reduced engagement [63]. Elements such as favicons, the small symbols displayed in browser tabs next to the site title, and logical site architecture enhance UX by aiding user recognition and ensuring accessibility for search engines, contributing to elevated SEO performance [14], [63].

Website Load Speed

Website load speed significantly influences both user satisfaction and search engine rankings. Gopalakrishna [28] refers to an article by Google highlighting that 53% of mobile users abandon sites that take longer than three seconds to load with the bounce rate increasing by 90% as load times extend from one to five seconds. To achieve fast initial load times, techniques such as image compression, code minimization, lazy loading of components, and elimination of render-blocking resources are critical [28], [14]. Compression of HTML, CSS, and JavaScript files using tools like Gzip reduces file sizes, accelerating loading times [14]. Additionally, optimizing browser caching ensures static assets are stored locally on user devices, minimizing redundant data requests [57], [59].

The selected hosting infrastructure should be reliable, offer high uptime, fast server response times, and geographical server distribution to reduce latency [57]. Employing Content Delivery Networks (CDNs) enhances speed by delivering content from geographically closer servers, reducing latency and load times [59]. These measures also contribute to better Core Web Vitals scores, including Largest Contentful Paint (LCP), First Input Delay (FID), and Cumulative Layout Shift (CLS), all of which Google prioritizes in its ranking algorithms [45], [54]. Gopalakrishna [28] refers to Ahrefs article stating that websites with sub-two-second

load times see significantly lower bounce rates (9.6%) compared to those that take five seconds (38%). These optimizations not only improve user experience but also position websites higher in search engine results, as speed remains a decisive factor in Google's ranking algorithms [59].

Responsive Design and Mobile Optimization

With the growing dominance of mobile devices for web browsing, optimizing websites for mobile use is crucial for improving both user experience and search engine rankings. Google, in particular, prioritizes mobile-friendly websites, giving them a boost in search rankings [35], [36], [59]. Mobile optimization involves more than just resizing images or text; it requires a comprehensive approach that includes ensuring fast load times, touch-friendly navigation, and flexible layouts that adapt to various screen sizes [35], [36], [38].

One of the key components of mobile optimization is responsive web design. Responsive designs ensure that a website's layout adjusts seamlessly to different screen sizes. This dynamic approach improves the user experience, as it guarantees the content remains accessible and easy to interact with across all devices. Google's algorithm increasingly rewards websites with responsive design because it eliminates the need for separate mobile and desktop URLs, simplifying indexing and improving search engine rankings [59], [52]. Furthermore, a well-optimized mobile experience reduces bounce rates and increases user engagement, both of which are critical factors in SEO performance [35], [36], [59].

To further enhance mobile optimization, web developers should prioritize touch-based interactions and clear navigation to accommodate mobile users' unique browsing behavior [59]. Implementing large, well-spaced buttons and ensuring that links are easy to tap improves visibility, which can help retain visitors [35], [59]. Using viewport meta tags, optimizing images for faster load times, and testing for mobile friendliness are also essential steps [28], [36], [59]. Additionally, removing unnecessary elements and minimizing pop-ups enhances usability on smaller screens, while ensuring content remains accessible and easy to navigate [35], [36]. By following these best practices, developers can improve user engagement, reduce bounce rates, and ultimately boost the site's performance in search engine rankings [28], [36], [59].

5.3.5 Online Content

The Online Content SEO category of the framework includes factors related to creating and optimizing the content so that it aligns with user intent and search engine algorithms, and is relevant for the industry [53]. According to the literature, the primary goal is to create high-quality, relevant content that incorporates effective SEO techniques, including keyword optimization, diverse content formats, and semantic strategies. The literature emphasizes that achieving SEO success requires continuous effort in producing valuable content, ensuring readability, and adapting to evolving search engine standards.

Content quality is one of the most critical determinants of SEO success. Gopalakrishna [28] refers to a study by Semrush stating that content-related factors account for six of the top ten SEO ranking elements. High-quality content not only fulfills the immediate needs of users but also servers as a cornerstone for visibility and credibility on search engines [27], [63]. By investing in well-crafted, valuable, and relevant content, businesses enhance their digital presence and branding efforts while improving customer acquisition, both directly and indirectly [36], [67]. Additionally, prioritizing value-driven, educational content has been shown to increase customer engagement by up to 82%, further emphasizing its role in improving SEO outcomes [67]. However, while Dekate et al. [27], Gopalakrishna [28], and Tatikonda et al. [63] provide actionable strategies for achieving content excellence, others stress the inherent challenges due to the subjective and evolving nature of high-quality content. For example, Sezer Çırakoğlu [62] highlights that defining and creating high-quality content is difficult due to its dependence on audience preferences, industry standards, and the ever-changing expectations of search engines. This difference shows that content creators must balance practical strategies with adaptability to meet shifting standards.

Achieving sustainable SEO success requires consistent efforts in content creation and strategy. Effective practices include employing an SEO-friendly content management system (CMS) to make updates and metadata management easier [57]. Developing a structured content strategy with diverse formats – such as blogs, videos, and infographics – caters to varied audience preferences and improves SEO results [35], [57]. Key steps in this process include identifying audience pain points, addressing them through storytelling, optimizing for search engines, and tracking performance metrics [67].

Diversified content formats, including blogs, videos, and infographics, are vital for maintaining user engagement and enhancing SEO outcomes. Audiovisual elements, in

particular, improve user satisfaction and engagement [54], [63]. By leveraging various formats, websites can adapt to different user preferences, expand their reach, and increase interaction rates, all of which contribute to improved SEO metrics [63].

Gopalakrishna [28] and Singh et al. [45] emphasize the importance of semantic SEO. Gopalakrishna highlights that incorporating related terms and concepts enables comprehensive topic coverage, creating in-depth and authoritative content that addresses user queries effectively. Similarly, Singh et al underscore that semantic SEO requires content to be both relevant and updated, as the entire page's content helps create a "picture" that search engines analyze for alignment with specific user queries. Together, these perspectives suggest that semantic SEO involves both broad topic relevance and precise alignment with user intent.

Readability significantly influences SEO performance. The literature consistently highlights how text content should follow a logical structure, favor clarity, and employ visually appealing formats, such as short paragraphs and bulleted lists [58], [63]. Studies have demonstrated that adherence to readability principles, such as Grice's conversational maxims of quality, quantity, relevance, and manner, improves search engine rankings [62]. Additionally, metrics like the Flesch-Kincaid Grade Level show that simpler, more concise writing correlates with better SEO performance, higher engagement, and improvement rankings on SERPs [60].

5.3.6 Organic Local SEO

The SEO mix 6 O's framework defines the Organic Local SEO category to highlight the strategies and factors for optimizing a business's online presence for local, nearby or visitor customers, by improving visibility in local search results [53]. According to the literature, the primary goal of local SEO is to enhance a business's relevance for location-based search queries, utilizing techniques such as optimizing for local keywords, acquiring local citations, refining GMB profiles, and getting more customer reviews [27], [45]. Local SEO strategies are focused on targeting geographic regions, which allow businesses to reach users in their area and improve local search rankings [38], [45]. The importance of local SEO is emphasized in the literature, with studies highlighting how businesses can increase local visibility and engage more effectively with nearby customers by ensuring consistent accurate business information across various platforms and listings [45], [53]. These techniques are crucial for improving local search engine rankings, attracting foot traffic, and enhancing the online presence of businesses targeting local markets.

One of the key aspects of local SEO is the consideration of user intent and contextual factors. While changes in search results due to user activity have been deprecated, SERPs can still differ significantly based on factors such as location, time, and device. For instance, the query “restaurants near me” may yield different results depending on the user’s geographic location, the time of day, and the device used. [45] This underscores the dynamic nature of local search results, which are tailored to meet the specific needs of users in particular areas and contexts. Local SEO requires ongoing efforts to stay up to date with local search trends, consumer behavior, and search engine algorithm updates [53].

To optimize for local search success, businesses are encouraged to target their niche local customers rather than focusing on a broader, universal market. Local SEO helps businesses address regional needs while ensuring that their digital presence is aligned with local consumer behavior and preferences. [38] Implementing local SEO strategies such as optimizing for location-based keywords and maintaining an up-to-date GMB profile can significantly improve a business’s online visibility and make it more discoverable to local customers [28], [38].

In addition to the use of location-based keywords, local SEO also involves securing citations from other reputable local websites. Citations, which consist of a business’s name, address, and phone number (NAP), contribute to local SEO by confirming a business’s presence and legitimacy in a specific area [35], [45]. While the significance of citations has decreased in recent years, they remain an essential part of the local SEO landscape, as they help businesses appear in local search results when the NAP data is consistent and accurate across multiple online platforms. The NAP details should also be displayed on each page of the business’s own website, ensuring that potential customers can easily access business information, which improves user experience and improves SEO through adding more relevant content to the pages. However, inconsistencies or errors in NAP data can negatively impact local rankings, as search engines may interpret these inconsistencies as a signal of unreliability or misinformation. [45]

A critical component of local SEO is the optimization of GMB profiles. GMB serves as a business’s virtual storefront on Google, providing customers with essential information such as location, contact details, and hours of operation [27]. It also allows businesses to manage reviews, post updates, and respond to customer inquiries [45]. Maintaining an active GMB profile is crucial for local SEO, as it directly impacts a business’s appearance in local search

results, maps, and online directories [27]. Additionally, user interaction with the GMB profile, such as clicking on business photos, leaving reviews, and responding to questions, can positively influence local SEO rankings [45]. Furthermore, positive customer reviews on GMB play a significant role in enhancing local search visibility, as higher review ratings correlate with improved rankings in local search results [53]. This kind of behavioral signals and user engagement with the business's information act as additional ranking signals, helping improve a business's visibility in local searches [45].

In some cases, businesses may also consider language and localization as part of their local SEO strategy. For instance, specialized terms and product capabilities often remain untranslated or are transliterated due to the rapid pace of technological advancements and the difficulty of linguistic equivalence in target languages. This is particularly common in industries where specific terminology is essential for user understanding, and it may be influenced by SEO considerations to ensure consistency in search queries across different regions. For example, some websites may avoid translating technical terms, especially if the English versions are the most commonly searched by users in their respective regions, as it ensures they align with what potential customers are likely to search for. [64] In such cases, businesses optimize their web content by maintaining the original terms to align with their target market's global search behavior.

Furthermore, businesses expanding into new markets should consider developing a web platform in the local language, as visitors who primarily use that language are likely to make up the majority of the site's traffic. This approach not only helps create a localized experience but also improves the chances of the business appearing in search results specific to that region. [65] Additionally, the use of country-specific TLDs, such as .fi for Finland, or .uk for the United Kingdom, can further assist search engines in understanding the geographical target audience of the website, thereby improving local search rankings [53].

It is also critical to test keywords using the local Google Search domain for the region in which the business is operating. This allows businesses to optimize their content for regional search behavior and ensure that their website ranks well in local search engines, such as www.google.pt for Portugal, www.google.es for Spain, or www.google.co.uk for the UK [65]. Testing keywords across different domains can provide valuable insights into how to best tailor content to meet the needs of local customers.

5.3.7 AI in SEO

The literature shows several areas of SEO where AI can be utilized to improve the website for optimal search engine rankings. Literature highlights how AI can improve workflows, analyze large datasets, and personalize strategies, contributing to significant improvements in SEO [36]. In the literature, AI is seen as a tool for improving content quality, acquiring and accessing backlinks, keyword optimization, and improving technical SEO [36], [57], [72].

AI can be used to optimize the content creation process all the way from ideation to drafting, saving time and resources previously spent on manual efforts. AI can analyze large amounts of data and identify trends and consumer preferences, assisting with market research. Additionally, it enables strategic targeting of content to specific demographics and interests on social media platforms through data-driven analytics, ensuring that outreach efforts effectively engage relevant audiences. AI also personalizes content based on user preferences and behavior, delivering a more engaging and tailored experience. With advanced natural language processing and language generation capabilities, AI enhances user experience through dynamic interactions, such as chatbots, personalized content recommendations, and accurate responses, contributing to overall improved engagement. [36]

AI-powered tools can optimize content for search engines by performing keywords analysis, understanding user intent, improving readability, incorporating relevant links, and ensuring regular updates to maintain relevance and drive organic traffic. AI's capabilities extend to identifying relevant keywords, identifying trending topics, and detecting gaps in the market, helping to prioritize keywords effectively. For instance, AI can refine content quality by recommending relevant keywords, ensuring optimal keyword frequency, and improving keyword positioning. It can also analyze competitor content to understand which keywords are driving their rankings and suggest opportunities for improvement. Additionally, AI understands the context and semantics of keywords, facilitating more precise optimization approaches and enabling search engines to interpret content relevance more effectively. [36]
AI can be utilized to automate metadata generation based on content analysis to ensure alignment with targeted keywords [57]. For example, Vadlapati [72] presents a system called AutoTrendyKeywords, which utilizes Google Trends to automatically generate keywords and embed them in a site's meta tags and URL paths, solving the challenge of keywords becoming obsolete and removing the constant need to manually update the keywords to optimize SEO.

AI can also be used to enhance the process of generating and managing backlinks. By analyzing vast mounts of data, AI can identify relevant websites that present potential opportunities for backlinks, facilitating the time-intensive process of finding suitable link sources. Moreover, AI assesses the quality and relevance of backlinks, enabling a focus on high-value links that have the greatest impact on SEO performance. AI can also help personalize email outreach to website owners, tailoring messages to their specific interests and increasing the likelihood of successful collaboration and acquisition of backlinks. [36]

Another area where AI can be employed is technical SEO. AI can optimize various elements of a website, including site speed, crawlability, indexability, usability, and content quality, all of which contribute to better search engine rankings. For instance, AI facilitates website speed optimization by minimizing unnecessary complexity and ensuring efficient content delivery. Additionally, AI can analyze webpage content and automatically generate schema markup code, saving significant time compared to manual implementation while providing deeper semantic understanding that enables search engines to interpret website content more effectively. AI also reduces errors in schema markup implementation and recommends relevant schema structures, ensuring search engines correctly understand and display the site's information, ultimately improving search result performance. [36]

5.3.8 Measuring and Maintaining SEO

Measuring and maintaining SEO is essential for ensuring continuous improvement and achieving sustained visibility in the search engine results. SEO is a long-term strategy that requires time and consistent effort to deliver results, but when effectively implemented, it can significantly enhance a website's rank over time [55]. To maximize efficiency, SEO optimization should ideally begin during the website creation stage, as this approach minimizes the time needed for promotion in search engines [29]. Regularly measuring the effectiveness of SEO strategies is critical for identifying areas for improvement and achieving strong brand visibility [67]. This process involves setting up robust analytics and monitoring systems to track the performance of individual components of the strategy, with frequent checks and audits to enable timely adjustments and optimizations [54], [57].

Traffic and Visibility Related KPIs

The literature highlights the importance of various key performance indicators (KPIs) in measuring and optimizing SEO performance. Traffic and visibility related KPIs are crucial for

understanding the reach of a website. Metrics such as impressions, CTR, bounce rate, clicks, organic traffic, SERP rankings, keyword rankings, and conversion rates are essential for assessing how well a website attracts and retains visitors [35], [38], [57], [67]. These metrics are essential for understanding how often a webpage is retrieved by search engines, how frequently users access the site from search results, and how it ranks in search results, helping assess the website's visibility and SEO performance. Tracking organic traffic growth over a period, such as six months, can provide insights into the impact of SEO efforts and help assess long-term trends [67]. Search engine results can also be analyzed from a territorial standpoint to gain more localized insights [52].

Google Clicks is a KPI representing any click that directs a user to a page outside of Google Search Discover, or News, commonly tracked by professionals to assess visibility and traffic trends. This metric is typically reported monthly, making it ideal for short-term forecasting and for evaluating the effectiveness of SEO strategies. SEO forecasting tools, including advanced models like Prophet and simpler methods such as Random Walk with Drift, are designed to predict these Google Clicks, enabling practitioners to anticipate future performance. By leveraging these tools, SEO professionals can refine their strategies, better plan for future trends, and enhance their visibility and engagement. [71]

User engagement is another important aspect of SEO that can be measured through various KPIs. Metrics like bounce rate, session duration, and page views per session help evaluate user engagement with the website's content [67]. The usefulness and interestingness of a site to users are characterized by behavioral factors such as website traffic, failure rate, average time spent on the site, and the rate of returns to the site. Systematically monitoring these metrics using analytics programs allows for the identification and resolution of problems, improving user experience and contributing to increased site conversion rates. [29] To further analyze user behavior and intent, heatmaps and session recordings can be utilized to understand how users interact with a site [28].

Traffic-related KPIs can be measured with web analytics. Web analytics tools, such as Google Analytics, play a central role in monitoring user behavior and website performance [35], [55], [57]. For example, a higher bounce rate might indicate misaligned content or poor user experience, while longer session durations often suggest engaging and relevant material [28], [59]. Google Analytics allows for the tracking of acquisition channels, user engagement, and

conversion metrics, helping businesses better understand their audience and refine their strategies accordingly [57].

By establishing benchmarks and recording observations within Google Analytics, businesses can identify trends and performance gaps over time. Specific metrics, such as session counts, page views, and user categories for new and repeating visitors are particularly useful for evaluating a website's performance on both a local and global scale. [27] Moreover, data on user locations, preferred languages, and device usage offer additional layers of insight, enabling organizations to tailor content and design to meet audience preferences [28].

In addition to monitoring performance, web analytics facilitates iterative optimization by guiding adjustments based on real-time data. For instance, analyzing user behavior and traffic patterns can highlight opportunities for improving website design, enhancing user experience, and refining marketing campaigns [35]. Testing variations in page elements, such as call-to-action buttons or headline wording, further allows for data-driven decisions to improve engagement and conversion rates [35], [57].

Google Search Console is an essential tool for monitoring and optimizing a website's presence in Google Search results. It allows website owners to assess how their site is indexed and viewed by Googlebot, providing valuable insights into crawl errors, broken links, and other technical issues that may impact SEO performance [28], [35], [38]. By using Search Console, site administrators can promptly address these issues, ensuring that their content is accurately indexed and visible to users [57]. Additionally, the tool accelerates the process of indexing new or updated content, enabling faster appearance in search results. Search Console can also notify site administrators about indexing problems and other malfunctions, and it provides diagnostic tools for AMP pages to optimize for mobile users. [29]

Beyond technical troubleshooting, Search Console provides critical data on key metrics such as CTR, keyword performance, and traffic generated by specific queries. This information helps identify new keyword opportunities and highlights underperforming keywords that may require optimization. [59] By registering with Search Console, users gain a deeper understanding of how their site appears in search results, including query-specific impressions, clicks, and user behavior [29].

Technical KPIs

Technical KPIs are essential for understanding a website's health and performance from a technical standpoint. Core Web Vitals (CWVs) are part of Google's larger Web Vitals program, measuring critical aspects of the user experience. The three main parts of CWVs are Largest Contentful Paint (LCP), First Input Delay (FID), and Cumulative Layout Shift (CLS). LCP evaluates how quickly the main content of a website loads, FID measures the responsiveness of a website to user interactions, and CLS assesses the visual stability of a website during the loading phase. These technical metrics help ensure that a website provides a smooth and engaging experience for users. [59] Tools such as Lighthouse, WebPageTest, and Google PageSpeed Insights are commonly used to measure and optimize these metrics.

Lighthouse is Google's automated open-source tool for auditing web pages for performance, accessibility, SEO, and progressive web apps [38]. Key metrics provided by Lighthouse include the First Contentful Paint (FCP), Time to Interactive (TTI), and CLS, with recommended benchmarks of FCP under 1.8 seconds, TTI under 3.8 seconds, and CLS at or below 0.1. Integrating Lighthouse testing into the post-release process allows teams to monitor these metrics consistently, ensuring performance remains optimized and identifying regressions promptly. [28] The Lighthouse API further enables developers to automate these evaluations, embedding quality checks directly into their workflows [38].

WebPageTest offers another layer of insight by providing a detailed analysis of website performance focusing on metrics like Time to First Byte (TTFB), FCP, LCP, and CLS [28]. This tool identifies optimization opportunities such as implementing content delivery networks (CDNs), compressing images, and leveraging browser caching to improve website speed and user experience [59].

Google PageSpeed Insights complements these tools by delivering a free and comprehensive evaluation of website performance, separating results for desktop and mobile experiences. Key metrics include FCP, TBT, Speed Index, LCP, and CLS, along with actionable recommendations for improving speed and user experience. TBT is the sum of all periods between the FCP and TTI when the task length is more than 50 ms, and Speed Index indicates how quickly the page populates with visible content. [14] For instance, PageSpeed Insights highlights areas such as image optimization, CDN, and caching strategies [59]. Its API allows developers to integrate performance insights into their processes, enabling iterative improvements that align with user expectations and Google's performance benchmarks [38].

Other KPIs

One especially important KPI is the number of backlinks acquired, as an increase in quality backlinks can directly correlate with better search rankings [67]. There are several tools for assessing and managing backlinks. For example, Majestic specializes in backlinks analysis and is known for having one of the largest link databases in the world. It provides valuable insights into metrics such as Trust Flow (TF) and Citation Flow (CF), where Trust Flow evaluates the trustworthiness of a website based on the quality of incoming links, and Citation Flow measures the influence of a website by counting the number of links pointing to it. LinkChecker Pro is another tool, designed for backlink management, allowing users to monitor the status of backlinks, track Google indexing, check rel attributes and meta tags, and perform bulk analyses. [70]

There are also KPIs that are derived from multiple metrics, such as Visibility Index, which calculates the visibility and ranking position of a website's domain and subdomains in search results based on Google search rankings, search volume and competitive comparison. This metric can be tracked via tools, such as Sistrix, and it can help identify technical issues, track historical visibility, and ensure that SEO actions are producing the desired outcomes. [26]

SEO Audits

SEO audits are an important component of ongoing website optimization, helping identify areas for improvement and ensuring a website is aligned with best practices for search engine ranking. Tools can automate the auditing process, crawling every page on a website and reporting on essential elements like titles, descriptions, headers, and webpage status, thus eliminating the need for manual inspection and making the process more efficient. [55] There is a wide variety of SEO audit tools discussed in the literature. For example, Semrush offers comprehensive audits and competitor analysis, allowing users to track keyword rankings, monitor backlink profiles, and analyze competitor performance and strategies [28], [57]. Similarly, Ahrefs is a leading tool for backlink analysis and SEO auditing, providing extensive data on backlinks, organic search, and keyword rankings [38], [55], [70]. It can determine the Domain Rating (DR) and URL Rating (UR), which are key indicators of a domain's and individual web pages' authority, and also offers an API for accessing various SEO metrics [38], [55], [70].

Other useful audit tools include Seobility, which provides detailed performance data such as page quality, mobile optimization, and internal linking analysis, along with a task list to guide website improvements [14]. A tool called Neil Patel tracks page rank and performs SERP analysis to assess website visibility on Google [55]. SEO Site Checkup audits websites based on Google Search Essentials, evaluating factors such as SEO issues, server configuration, and speed optimizations [41]. For instance, Król et al. [66] used several SEO audit tools to evaluate websites, including WeNet audit SEO, Pixaura Free SEO Audit Tool, SEOmator Free SEO Audit Tool, AIOSEO SEO Analyzer, RankMath SEO Analyzer, Seobility SEO Checker, and SEO Tester Online.

SEO is a Continuous Process

SEO is an ongoing dynamic process that demands regular monitoring and measurement of the KPIs [28], [35]. Continuous evaluation of website performance is crucial to identify opportunities for optimization and to refine strategies over time [35]. Sahani et al. [57] recommend applying an iterative, agile, approach to SEO, ensuring that tactics are continuously refined based on data-driven insights, leading to more effective strategies. Constant evaluation is essential to identify promising niches and adapt strategies to meet evolving market conditions and consumer preferences [38], [59]. Regular monitoring enables businesses to make data-driven decisions, optimize user experiences, and ultimately enhance their digital performance [27]. By consistently monitoring, improving, and adjusting SEO factors, a webpage can achieve a higher position in Google's SERPs for targeted keywords [55].

To optimize content and user experience, conducting A/B testing regularly is recommended for comparing different SEO strategies and identifying the most effective ones for improving website performance [57]. Testing various page elements such as titles, meta descriptions and content structures enables continuous refinement and enhancement of the site's SEO [28]. Additionally, there should be streamlined processes for content creation, review, optimization, and publication to maintain a steady output of high-quality, SEO optimized content [57].

The literature consistently recommends implementing a regular audit schedule and conducting comprehensive SEO audits at least quarterly to identify and fix SEO issues as early as possible [28], [35], [57]. Daoud et al. [54], however, highlight how even monthly checks are often insufficient for detecting early signs of trouble, making more frequent evaluations critical to staying competitive. Regular audits and updates to the SEO strategy allow

businesses to adapt to changes in search algorithms, user behavior, and emerging trends, which is vital for maintaining high search engine rankings [28], [35]. As search engine algorithms evolve, staying informed about major updates becomes essential to avoid missing significant changes that could affect the website's performance [54]. SEO strategies must adapt quickly to these updates to ensure the continued effectiveness of optimization efforts. Moreover, technical SEO should be viewed as an ongoing process, with regular audits and performance monitoring using tools like Lighthouse, WebPageTest, and Google PageSpeed Insights to measure Core Web Vitals and promptly address any technical issues that may arise. [28]

5.3.9 Programmatic SEO

The literature had no mentions of programmatic SEO, which is a significant research gap. There was exactly one research paper that did essentially what is pSEO based on the definition: Muñoz-Terol et al. [52] created video streaming meta platform video pages programmatically and modified page title, description, and the main heading elements for each page. They generated pages with the same layout for each video to rank on Google, which is indeed pSEO. pSEO will be further discussed in chapter 6.

5.4 Summary of the Review

A comprehensive literature review was conducted in this chapter to find answers to the research questions from novel scientific literature. A good number of papers, 31 in total, were selected after a thorough examination of the material returned by the search queries. The literature was particularly relevant for research questions RQ1 and RQ4, while there was less, though sufficient, relevant material for RQ3, and practically no material at all for RQ2. Tables 8-15 summarize the most important findings from the literature into actionable items for improving SEO in different areas.

RQ1, "How to improve the visibility of a web application in Google search results?", is addressed through the actionable items in Tables 8-14 focusing on optimizing on-page SEO, off-page SEO, technical SEO, user experience, online content, organic local SEO, and utilizing AI in the SEO efforts.

RQ4, "How can SEO performance of a web application be measured using Google's tools, and how can these measurements be used to improve SEO in a deployed application?", is

answered by Table 15, which provides actionable items for measuring and maintaining SEO performance through tracking relevant KPIs related to traffic, visibility, user engagement, and technical aspects, utilizing SEO forecasting, employing web analytics and Google Search Console, running regular SEO audits, and conducting A/B testing. Based on all of these techniques, data-driven changes and improvements can then be made to the website to improve SEO.

RQ3, “How can SEO be implemented in a multi-locale application to improve visibility in Google Search results?”, is mostly covered in the literature in the context of local SEO. The actionable items in

Table 13 answer how to improve SEO for a single locale, but the literature alone does not clarify how to extend this knowledge into optimizing a single application for multiple locales. However, all of these techniques seem easily scalable such that to optimize a multi-locale application in different regions, one would simply need to perform the same actions for different target areas. The key local SEO techniques include local keyword optimization, local citations, GMB optimization, customer reviews, targeting niche local audiences, NAP consistency, localization of content, testing keywords on local domains, and country-specific domains.

RQ2, “How to utilize programmatic SEO to improve visibility of a web application in Google Search results?”, can not be answered by this literature review. There is only one paper that employs pSEO, but that paper does not even mention the term. This single example of conducting pSEO could provide some direction but is clearly not enough for making any deeper conclusions. Therefore, further research is required to determine the optimal practices related to pSEO. Further research on pSEO will be conducted in chapter 6.

Based on the literature, all of the SEO areas are important, and lacking in any of them may have a significant negative impact on SEO performance [36], [38], [54], [59]. To achieve the greatest improvements, it is essential to focus efforts on the areas that will yield the most impactful results. By regularly measuring and auditing, as outlined in Table 15, one can identify which aspects of SEO require the most attention, ensuring that resources are directed toward the activities that provide the highest value. This approach helps maximize the effectiveness of optimization efforts and ultimately enhances the website’s visibility in search engine results.

Table 8. On-Page SEO Recommendations

Target	**Recommendations**
Keyword Optimization	Conduct thorough keyword research, form a semantic core, and strategically integrate keywords across titles, metadata, headings, content and URLs
Page Title	Define a unique, relevant title for each page, include the main keyword and brand name when applicable, keep it between 40-65 characters, and avoid stop words.
Description Meta Tag	Define a unique meta description for each page, include relevant keywords, minimize stop words, keep it between 125-160 characters, and consider using emojis or a call to action.
Keywords Meta Tag	Do not use the keywords tag.
Heading Tags and Semantic HTML	Use semantic HTML and heading tags <h1> to <h6> correctly in hierarchical order. Ensure that each page has a single <h1> with relevant keywords.
Domain Name	Use a domain name that aligns with the brand name. If there is no brand, include relevant keywords. The ideal length is under 15 characters. Avoid hyphens.
Page URLs	Ensure logical structure, include relevant keywords, keep them short, use hyphens to separate words. Avoid dynamic URLs in favor of static ones.
Content and Keywords	Use relevant keywords naturally throughout the content. Focus on long-tail keywords for niche topics. Keep keyword density below 8% and avoid keyword stuffing. Ensure the content is meaningful and detailed.
Image Optimization	Optimize image attributes (alt, title, captions, filenames) with relevant keywords. Compress images, use WebP format, use responsive images, and utilize lazy loading for off-screen images.

Table 9. Off-Page SEO Recommendations

Target	**Recommendations**
Backlinks	Acquire high-quality, relevant backlinks through strategies such as guest blogging and content partnerships.
Reviews and Testimonials	Encourage customers to leave genuine reviews and testimonials.
Social Media Signals	Encourage content sharing on social media, engage with followers, get likes, comments and shares.

Table 10. Technical SEO Recommendations

Target	**Recommendations**
Architecture	Utilize SSR, implement Isomorphic JS with prerendering, minimize JS for faster load times, ensure SEO-friendly database schema, setup redirects for SPA error pages
Mobile-First Design and Accelerated Mobile Pages	Ensure mobile-friendly design and implement AMP pages.
HTTPS Protocol	Use HTTPS.
Domain	Choose a reputable TLD and maintain domain age.
Internal Linking	Structure internal links logically, use descriptive anchor text, avoid excessive links.
Broken Links and Redirects	Set up 301 redirects for changed URLs and avoid automatic redirects that confuse users.
Duplicate Content and Canonicalization	Use the “rel=canonical” tag when multiple URLs point to the same content.
Language Metatag	Include the correct language metatag.
Robots.txt	Update the robots.txt file to guide search engine bots on which pages to crawl.
XML-sitemap	Create and update an XML sitemap to ensure search engines crawl important pages.
Schema Markup	Implement schema markup for richer search results.

Table 11. Optimized User Experience Recommendations

Target	**Recommendations**
General UX	Simplify navigation and design for seamless user experience.
Website Load Speed	Compress files, optimize caching, and use CDNs.
Responsive Design and Mobile Optimization	Use responsive design, prioritize touch-based interactions, use large buttons, remove unnecessary elements.

Table 12. Online Content Recommendations

Target	**Recommendations**
Content Quality	Create high-quality, valuable content that meets user needs and aligns with search engine algorithms.
Consistent Content Creation	Develop a content strategy with a regular production schedule.
SEO-friendly CMS	Use an SEO-friendly content management system for easy content updates and metadata management.
Diverse Content Formats	Produce a mix of content formats, such as blogs, videos, and infographics to engage different audience preferences.
Semantic SEO	Incorporate related terms and concepts to create comprehensive, authoritative content aligned with user queries.
Readability	Ensure content follows a clear, logical structure with short paragraphs, clear sentences, and bullet points for better readability.

Table 13. Organic Local SEO Recommendations

Target	**Recommendations**
Local Keyword Optimization	Optimize content with location-based keywords.
Local Citations	Secure accurate and consistent citations with NAP from reputable local websites.
Google My Business Optimization	Maintain an active and complete Google My Business profile.
Customer Reviews	Encourage positive customer reviews on Google My Business.
Target Niche Local Audiences	Focus on addressing regional needs to better align with local customer behavior.
NAP Consistency	Ensure business name, address, and phone number are consistent across all platforms.
Localization of Content	Localize content to match regional search behavior and terminology.
Testing Keywords on Local Domains	Test keywords on local Google domains.
Country-Specific Domains (TLDs)	Use country-specific TLDs to help search engines identify the geographical focus of the business.

Table 14. AI in SEO Recommendations

Target	**Recommendations**
AI-Powered Content Optimization	Utilize AI to optimize content creation, keyword usage, and personalization based on user behavior.
AI for Backlink Strategy	Employ AI to identify high-quality backlink opportunities.
AI for Technical SEO	Use AI to optimize site speed, crawlability, and generate schema markup.
AI for Market Research and Strategy Personalization	Leverage AI to analyze market trends, identify high-performing keywords, and personalize content targeting specific audiences.

Table 15. Measuring and Maintaining SEO Recommendations

Target	**Recommendations**
Traffic and Visibility Related KPIs	Monitor key SEO metrics such as CTR, bounce rate, organic traffic, keyword rankings, impressions, clicks, and conversion rates to assess the website's performance.
SEO Forecasting Tools	Use SEO forecasting tools to predict traffic trends and refine strategies.
User Engagement	Measure user engagement using metrics like session duration and page views per session to assess content effectiveness.
Web Analytics	Leverage web analytics, such as Google Analytics to track acquisition channels, user behavior, and conversion rates for informed strategy adjustments.
Google Search Console	Optimize the website using Google Search Console to monitor indexing, crawl errors, and technical issues impacting SEO.
Technical KPIs	Monitor Core Web Vitals such as LCP, FID, and CLS to enhance UX and site performance.
Regular SEO Audits	Run regular SEO audits with tools such as Semrush or Ahrefs to identify gaps and ensure optimal SEO practices.
A/B Testing	Apply A/B testing to continuously refine SEO strategies.

6 Qualitative Content Analysis on Programmatic SEO

Since there is very little academic research on pSEO, as discussed in chapter 5, this chapter turns to online sources to explore the topic further. Qualitative content analysis is performed to examine blog articles and other digital materials to define pSEO and identify best practices for its implementation. By applying a structured approach to data collection and analysis, this chapter aims to provide a clearer understanding of pSEO and its effective execution, therefore providing essential insights for answering RQ2: "How to utilize programmatic SEO to improve visibility of a web application in Google Search results?"

6.1 Material Collection

To ensure a comprehensive and structured analysis of pSEO, the material collection process was carefully designed around three key focus areas: 1) the definition of programmatic SEO, 2) best practices, strategies, and techniques, and 3) practical case examples and success stories. These categories guided the selection of search queries and helped in gathering relevant online sources.

To ensure the credibility and relevance of the collected materials, the following inclusion criteria were applied:

- The author or organization must be identifiable and considered an expert in SEO or a related field.
- The text must explicitly use the term "programmatic SEO".
- The material must have been published in 2020 or later. If no publication date is available, the content's recency is evaluated based on contextual clues, such as references, examples, or mentioned technologies.

The searches were conducted on February 17, 2025, using Google Search in a private browsing window within Mozilla Firefox. To maintain relevance, Google's search tools were utilized to filter results published after January 2020, ensuring that only recent insights were included. The first ten organic search results were inspected for each query, while advertisements were deliberately excluded to maintain objectivity.

The search process was divided into three query sets based on the key focus areas, as outlined in Table 16. The table presents the search queries used, along with the number of analyzed

results and the count of unique articles selected for each set. Additionally, it shows the cumulative total unique articles after each stage, resulting in the final dataset of 42 unique articles. This systematic approach to material collection ensures that the selected sources provide a balanced, up-to-date, and well-documented foundation for the qualitative content analysis in the following sections. The analyzed articles are shown in Table 17.

Table 16. Search Process and Results.

Query Set	**Search Queries**	**Total Results Analyzed**	**Unique Articles**	**Cumulative Unique Articles**
Definition of Programmatic SEO	- What is Programmatic SEO? - Definition of Programmatic SEO - Introduction to Programmatic SEO	29	19	19
Practices, Strategies, and Techniques	- Best practices for Programmatic SEO - Programmatic SEO strategies - Techniques for implementing Programmatic SEO	30	19	27
Practical Case Examples and Success Stories	- Programmatic SEO case studies - Examples of successful Programmatic SEO implementations - Real-world applications of Programmatic SEO	30	18	42

Table 17. Analyzed articles

#	**Title**	**Article Type**	**Publisher / Author**	**Year**	**Ref.**
1	What is Programmatic SEO? Does Your Business Need It?	Blog	Tru Performance	2025	[77]
2	What is Programmatic SEO? [How to do it in 4 simple steps]	Blog	Growth Minded Marketing / Ray Olaibi	2024	[78]
3	What Is Programmatic SEO and Why Is It So Effective?	Blog	Webstacks / Devon Wood	2024	[79]
4	What is programmatic SEO & how does it work?	Blog	Mangools / Ksenija Drobac	2024	[80]
5	The Complete Guide to Programmatic SEO	Course	Daydream / Multiple contributors	2024	[81]

#	Title	Article Type	Publisher / Author	Year	Ref.
6	3 Programmatic SEO Examples Worth Your Attention	Blog	SEOmatic / Minh Pham	2023	[82]
7	Programmatic SEO: Your missing link to 1M+ sessions	Blog	Search Engine Land / Jake Gronsky	2022	[83]
8	Programmatic SEO: What It Is and How to Implement It	Blog	WebFX / Sina Mchunu	2023	[84]
9	Programmatic SEO: What Is It And How To Do It	Blog	Break The Web / Jason Berkowitz	2025	[85]
10	Programmatic SEO: What Is It & How To Do It	Blog	NP digital / Neil Patel	2024	[86]
11	Programmatic SEO: What Does It Mean & How to Do It?	Blog	SEOmator	(?)	[87]
12	Scaling Organic Traffic with Programmatic SEO: Examples and How-to	Blog	Flow / Sofie Couwenbergh	2024	[88]
13	Programmatic SEO: Strategies, Examples, and Getting Started	Blog	Rock Content	2024	[89]
14	Programmatic SEO: Meaning, Pros and Cons, Tools & Examples	Blog	VH-info	2024	[90]
15	Programmatic SEO: How to increase search traffic with no-code tools	Blog	Zapier / Luciano Viterale	2023	[91]
16	Programmatic SEO: Create Thousands of Web Pages That Convert	Blog	Semrush Team	2023	[92]
17	Programmatic SEO: An Introduction To Pages At Scale	Blog	Search Engine Journal / Dan Taylor	2025	[93]
18	Programmatic SEO: A Comprehensive Guide 2024	Blog	OpenWeb in LinkedIn	2024	[94]
19	Programmatic SEO: A Beginner’s Guide (with Examples)	Blog	Positional / Nate Matherson	2024	[95]
20	Programmatic SEO, Explained for Beginners	Blog	Ahrefs / Ryan Law	2023	[96]
21	Programmatic SEO Introduction For Beginners: Detailed Guide	Blog	Shout Me Loud / Harsh Agrawal	2024	[97]
22	Programmatic SEO examples: the ultimate list with use cases	Blog	BCMS / Arso Stojović	2022	[98]
23	The best programmatic SEO examples out there	Blog	Bullet / Nagarathinammal	2024	[99]
24	Programmatic SEO Examples	Course Website	Practical Programmatic	(?)	[100]
25	Programmatic SEO Examples That Actually Work	Blog	StoryChief Insights / Ilias Ism	(?)	[101]
26	Programmatic SEO case study: How UserPilot Scaled to 100K Visitors in 10 Months	Blog	How the F*ck / Ben GOodey	2022	[102]
27	Programmatic SEO and eCommerce: What are some best practices?	Blog	Hutte / Mehdi Boufous	(?)	[103]

#	Title	Article Type	Publisher / Author	Year	Ref.
28	Programmatic SEO: A comprehensive guide	Blog	Oncrawl / Nick Brown	2022	[104]
29	Programmatic SEO – How to do it for B2B SaaS	Blog	Medium / Arpit Mishra	2024	[105]
30	Programmatic SEO – Getting It Right	Blog	HubSpot / Jenny Romanchuk	2025	[106]
31	How to Overcome the 6 Most common Programmatic SEO Challenges	Blog	Postdigitalist / Iñaki Higuera	2024	[107]
32	Exploring programmatic SEO: Real-world examples and insights	Blog	Search Engine Land / Tom Demers	2023	[108]
33	Case Study: The Programmatic SEO Approach that Got Attention from Oracle and Google	Case Study	Diggity Marketing / Matt Diggity	2024	[109]
34	A Step-by-Step Guide to Getting Started with Programmatic SEO	Blog	Area Ten / Jeremy Tang	2024	[110]
35	19 SEO Case Studies to Improve Your Strategy in 2025	Blog	AIOSEO / Gabriela Jhean	2025	[111]
36	12 Actionable SEO Examples to Inspire Your Strategy	Blog	SEO.com / Abbey Stephan	2024	[112]
37	8 Programmatic SEO Case Studies: See What Strategies Work	Blog	SaaS Launchr / Jenn Pereira	2024	[113]
38	8 Powerful Tips to Execute Programmatic SEO with AI [2025 Guide]	Blog	Omnius / Srdjan Stojadinovic	2025	[114]
39	6 Best Programmatic SEO Examples to Steal Ideas From	Blog	Omnius / Ana Pantic	2024	[115]
40	5 Programmatic SEO Examples	Blog	SEOcasestudy.com / Ben Goodey	2023	[116]
41	5 Programmatic SEO Examples to Capture More Leads for Your SaaS Products in 2025	Blog	Concurate / Priti Sohal	2025	[117]
42	4 Programmatic SEO examples for B2B SaaS to get you inspired	Blog	Flying Cat / Bree Recker	2023	[118]

6.2 Methodology

The research was conducted using qualitative content analysis. A similar methodology was employed, for example, in Nevala's thesis [119], which also studies SEO. Qualitative research and content analysis are discussed thoroughly in the book by Tuomi and Sarajärvi [120]. In their book, they outline the following steps for performing qualitative content analysis:

1. Make a strong decision about what interests you in the material.

2a. Go through the material, separate and mark the things that relate to the chosen interest.

2b. Everything else is excluded from research.

2c. Gather the marked items together and separate them from the rest of the material.

3. Classify, theme, or categorize the material.

4. Write a summary.

The research in this thesis is based on material-driven analysis and classification. Tuomi and Sarajärvi refer to Miles and Huberman in their book when they define a three-step process for qualitative material-driven analysis. The steps are 1) data reduction, or simplification; 2) data clustering, or grouping; and 3) abstraction, or the creation of theoretical concepts.

As stated in the book, before starting the analysis, it is essential to define a unit of analysis, which can be a single word, sentence, or concept. This unit should be defined based on the research objective and the selected material. The step of data reduction includes excluding everything from the research that is not relevant to the research. Then in the clustering step, the picked expressions are analyzed to look for concepts that describe similarities or differences. The concepts are then grouped and combined into subclasses. The subclasses are then further combined into super classes. It is common to then count occurrences of items in each subclass and superclass.

In this research, the unit of analysis is based on RQ2, “How to utilize programmatic SEO to improve visibility of a web application in Google Search results”. The goal is to define pSEO and to find all the concrete steps and techniques required to successfully utilize pSEO to improve visibility of a web application in Google Search results. Therefore, the unit of analysis consists of the definitions of pSEO and pSEO techniques.

The material was first read through, while picking all the relevant parts from the material. The parts were considered relevant when they directly provided information related to the unit of analysis. The picked parts were then reduced to simpler and shorter expressions for use in the next steps of the analysis.

Occurrences of each technique were counted, and their popularity was then determined based on the number of occurrences. The popularity of a technique is considered as an indicator of

the importance of the technique. The occurrences can also be used to show the most popular and important areas of interest for SEO.

6.3 Results

This section presents the findings of the qualitative content analysis, which aimed to achieve two key objectives: first, to define pSEO, and second, to identify the concrete steps and techniques involved in its implementation. The results are organized into two subchapters, one focusing on defining pSEO and the other detailing the various techniques and strategies derived from the analysis.

6.3.1 Definition of Programmatic SEO

Since scientific literature had practically no mentions of pSEO, it is beneficial to form a proper definition for it. All the 42 articles collected for this content analysis were analyzed, and 33 of them provided their own definitions for pSEO. The definitions are listed in Table 18. The goal of this analysis was to identify common themes, detect potential outliers, and synthesize a comprehensive definition that encapsulates the core aspects of pSEO. The definition is provided at the end of this subchapter.

Table 18. Programmatic SEO Definitions

Definition	**Ref.**
“Programmatic SEO is an automated approach to creating and optimizing large volumes of web pages tailored to specific long-tail keywords”	[77]
“Programmatic SEO (also known as pSEO) is the process of creating keyword targeted web pages automatically. The pages use a template and a few elements that automatically change based on keywords or other criteria.”	[78]
“Programmatic SEO (pSEO) is the method of mass-producing pages of content using a database to rank high in Google’s search results for similarly-structured, long-tail keywords.”	[79]
“Programmatic SEO, also known as pSEO, is an automated or semi-automated approach to creating and optimizing landing pages on a large scale targeting thousands of keywords.”	[80]
“Programmatic SEO uses automation and structured data to create a large volume of unique web pages optimized for long-tail keyword variations.”	[81]
“It [Programmatic SEO] helps you generate landing pages on a large scale by using templates that can dynamically insert data from a database with the goal of targeting very niche audience and specific search terms.”	[82]
“Programmatic SEO is the strategy of publishing unique, high-quality pages at scale using a template and a database. The goal of programmatic SEO is to create content with the same depth and thoroughness as a traditionally published article but repeated thousands, if not millions, of times at scale.”	[83]
“Programmatic search engine optimization (SEO) is the use of automation and technology to improve a website’s performance in search results. It entails using computer programs and	[84]

Definition	Ref.
algorithms to assess data, make informed decisions and implement changes that might raise a website's search engine rankings."	
"-- programmatic SEO is a method that addresses the growing amount of search traffic by publishing landing pages on a large scale."	[85]
"Programmatic SEO is an approach to search engine optimization that uses automation to create large numbers of pages, each targeting specific, low-competition keywords. Unlike traditional SEO, where content is manually crafted for each keyword, programmatic SEO relies on templates and automation tools to generate hundreds—or even thousands—of pages at scale."	[86]
"Programmatic SEO refers to automating the processes that are typically done manually in search engine optimization. This includes identifying and creating content for long-tail keywords and creating landing pages at scale. "	[87]
"Programmatic SEO (pSEO) is a search engine optimization strategy that entails creating and publishing a large number of web pages using one or more databases that feed information into a page template. Each of the pages created this way targets a specific long-tail keyword pattern or a modification of a head term."	[88]
"Programmatic SEO (pSEO) utilizes technology and templates to create multiple landing pages centered around low-competition keywords. The goal is to craft a unique and compelling template that can be repeated and adjusted as needed to target nearly identical keywords within the same space"	[89]
"Programmatic SEO is a strategic approach to search engine optimization that involves creating a large number of web pages at scale using automated tools and templates"	[90]
"Programmatic SEO is a way to create a bunch of SEO-optimized web pages at once, using existing data and pre-programmed rules"	[91]
"Programmatic SEO involves creating landing pages on a large scale to rank on search engine results pages (SERPs). It's sometimes referred to as pSEO."	[92]
"Programmatic SEO is an approach to SEO and content creation that leverages automation and technology to efficiently create, optimize, and manage a large volume of webpages."	[93]
"Programmatic SEO refers to the use of automation and technology-driven solutions to optimize and manage various aspects of search engine optimization. – – programmatic SEO leverages algorithms, machine learning, and data analysis to streamline processes and drive results."	[94]
"pSEO is the process of quickly creating a very large number of pages on your website, often using a data source and landing pages."	[95]
"Programmatic SEO refers to the creation of keyword-targeted pages in an automatic (or near automatic) way. It provides a way for companies to create thousands of website pages targeted at thousands of keywords—without having to design, write, and publish pages manually."	[96]
"Programmatic SEO, also known as pSEO, is a strategy that leverages data and custom APIs to create a large number of landing pages at scale. -- Each page is based on a template that contains the same elements, such as reviews, images, pricing, and more. Using automated tools and a dataset, variations of the pages can be created, each targeting a specific keyword."	[97]
"Programmatic SEO is the method of mass-producing pages of content using a database to rank high in Google's search results."	[98]
"Programmatic SEO is a strategy that leverages automation and technology to efficiently create and optimize large volumes of unique, high-quality web pages, aiming to rank for a wide range of keywords."	[99]

Definition	Ref.
“Programmatic SEO is an SEO strategy that involves using automation and technology to create and optimize a large number of unique, high-quality web pages at scale in order to rank for a high amount of keywords.”	[101]
“Programmatic SEO is a method by which hundreds or thousands of pages with content created addressing simple, repeatable key phrases on Google. These keywords are almost always the “long tail” end of the curve (and not “too competitive”) keywords. “	[103]
“Programmatic SEO is a tool that lets you create large numbers of pages using specialized code. The pages it creates for you are based on keywords, which you select or input to tell the program what sorts of pages it should make. Programmatic SEO can help you create a lot of different yet similar landing pages that target specific keywords and/or variations on groups of keywords. This way, you can ensure potential customers find their way to a landing page tailored to the keyword they typed into their search engine.”	[104]
“Programmatic SEO is about automating the creation of web pages to target a wide range of specific queries. Think of it as mass-producing pages, each tailored for a different, often particular topic or keyword phrase.”	[105]
“With programmatic SEO (or pSEO), you are making pages that target keywords nearly automatically. Thanks to programmatic SEO, you can generate hundreds to thousands of landing pages designed to target hundreds to thousands of keywords — but you don’t need to spend time creating those pages manually, which saves a lot of time. To do this, you’ll fetch data from and use pre-programmed rules. So, where do humans come into the picture? Only to fact-check the data and fill in the databases.”	[106]
“Programmatic SEO (often referred to as pSEO) involves creating landing pages at scale through automation with the aim of ranking them on the search results pages. Each page is uniform, targets a single unique keyword and is created using automated tools and a database.”	[109]
“Programmatic SEO refers to the automated process of optimizing web pages for search engines. -- programmatic SEO uses automation tools to create and optimize thousands of pages simultaneously. Key Characteristics: Automation: Use of scripts, algorithms, and tools to automate SEO processes. Scalability: Ability to optimize thousands of pages at once. Data-Driven: Leveraging data insights to target keywords and optimize content.”	[113]
“Programmatic SEO (pSEO) involves using automated methods and data-driven techniques to create and optimize large quantities of web pages.“	[115]
“The strategy of publishing unique, high-quality pages at scale using a template and a database”	[116]
“pSEO is a marketing strategy that uses automated processes and scripts to generate large numbers of web pages and optimize them for search engines.”	[118]

Through systematic analysis, six recurring elements emerged across the majority of definitions:

1. Automation and Technology: A dominant characteristic of pSEO is its reliance on automation, algorithms, and scripts to generate and optimize content at scale. Common terms in the definitions: automation, technology, pre-programmed rules, AI, and data-driven methods.

2. Large-Scale Page Creation: A defining trait of pSEO is the creation of hundreds, thousands, or even millions of pages automatically. Common terms in the definitions: at scale, mass-producing, bulk, and thousands of pages.

3. Use of Templates & Databases: Many definitions highlight the use of templates and structured data sources to dynamically populate web pages. Common terms in the definitions: templates, structured data, database-driven, dynamic content, API-driven pages.

4. Targeting Long-Tail Keywords: Most of the definitions emphasize targeting niche, low-competition, long-tail keywords to improve search rankings. Common terms in the definitions: long-tail keywords, keyword variations, low-competition keywords, head term modifications.

5. SEO Optimization & SERP Ranking: The fundamental purpose of pSEO is to enhance search visibility and improve rankings in SERPs. Common terms in the definitions: rank high in Google, optimize for search engines, improve search performance.

6. Content & Landing Page Optimization: While some definitions focus purely on scale, others stress the importance of high-quality, SEO-friendly, and unique content. Common terms in the definitions: unique web pages, high-quality content, optimized pages.

While most definitions align with the core themes, one definition [84] deviates in a meaningful way. It describes pSEO as general automation in SEO, failing to specify mass generation of pages, utilization of templates, or targeting long-tail keywords. This definition was thus removed from the analysis.

Based on the common themes, the following definition was formed, encapsulating the essence of Programmatic SEO:

> Programmatic SEO (pSEO) is a data-driven approach to search engine optimization that leverages automation, templates, and structured data to create and optimize large volumes of web pages at scale, primarily targeting long-tail keywords to improve search rankings.

6.3.2 Programmatic SEO Techniques

A wide range of pSEO techniques was collected from various articles, each presenting slightly different wording and areas of focus. To streamline the insights, closely related techniques were consolidated into concise technique descriptions, forming distinct subclasses. These subclasses were then grouped into seven superclasses, each representing a different area of pSEO: 1) Developing a pSEO Strategy, 2) Conducting Keyword Research for pSEO, 3) Designing and Building Programmatic Pages, 4) Creating the Content for the Pages, 5) Managing Sitemaps, 6) Maintaining and Improving the Pages, and 7) Acquiring Backlinks. The following sections explore each superclass in detail, outlining the essential techniques within them.

Developing a pSEO Strategy

The majority of the articles mention techniques related to developing a pSEO strategy, which resulted in seven unique techniques as outlined in Table 19. A strong pSEO strategy is essential for ensuring that large-scale, automated content aligns with search intent and drives meaningful traffic. Since pSEO is particularly effective for transactional and commercial search intent, where users are actively looking for products or services, it is crucial to build a strategy that prioritizes these intents. For instance, one of the articles highlights, "*Programmatic SEO generally works best for transactional and commercial intent, because informational and navigational intents are hard to cover with template landing pages*" [78].

The most frequently mentioned technique in this category is *conducting in-depth niche, competitor, and audience research*, with a total of 16 references. Understanding the competitive landscape and target audience allows businesses to identify opportunities for scalable content. This foundational research informs keyword selection, page templates, and content strategy.

Closely related to this is *mapping customer behavior to search patterns, intent, and product alignment*, which has 11 references. By analyzing how users search for products or services, businesses can optimize their programmatic pages to match high-intent queries, which increases conversion potential.

Planning how pages drive users into the conversion funnel is another key strategy, with five references in the articles. While programmatic pages can capture traffic efficiently, they must also guide users toward conversions, which could be achieved through clear CTAs, product

recommendations, or internal linking structures. This is essential for the strategy to ensure that the pSEO campaign provides value for the business.

Less frequently mentioned but still significant is *building an SEO-optimized foundation before scaling*, with three references. This approach emphasizes setting up a strong site structure, base content, and editorial material before expanding with large-scale programmatic pages. Without a solid foundation, pSEO efforts may struggle with indexation, authority, and user experience.

Some techniques, despite being crucial, appear infrequently in the gathered references. *Defining objectives and setting KPIs*, has only one reference in the materials, although it is a key part in any strategy as it allows tracking progress and ensures that pSEO efforts are aligned with business goals. This technique is likely not mentioned in the materials because it is assumed as a standard SEO best practice, instead of being special to pSEO. Similarly, *creating a content plan aligned with keyword strategy*, has only one reference, while it is essential for ensuring consistency and effectiveness across programmatic pages. Another technique with only one reference is *gathering customer questions from support channels*, which can uncover valuable content opportunities, particularly for long-tail queries that may not be immediately apparent from keyword research alone. While some of these techniques appear less frequently in the reviewed articles, their importance should not be underestimated. To form a successful pSEO strategy, all these techniques should be considered.

Table 19. Developing a pSEO Strategy

Technique	**n**	**References**
Conduct in-depth niche, competitor, and audience research.	16	[80], [81], [82], [83], [84], [88], [90], [91] [92], [93], [95], [105], [106], [110], [111], [118]
Map customer behavior to search patterns, intent, and product alignment.	11	[80], [81], [82], [83], [84], [90], [93], [103], [110], [111], [117]
Plan how pages drive users into funnel.	5	[80], [81], [82], [83], [84]
Build the SEO-optimized foundation of the website with good structure base content, editorial or blog content, first before scaling.	3	[95], [110], [114]
Define objectives for pSEO. Set KPIs with metrics (traffic growth, conversions, rankings) to track progress.	1	[93]
Create a content plan that aligns with keyword strategy and search intent.	1	[90]
Gather customer questions from chats, emails, and support tickets to identify content opportunities.	1	[106]

Conducting Keyword Research for pSEO

Effective keyword research is essential for the success of a pSEO strategy, enabling programmatic pages to target the most relevant search queries at scale. By identifying and targeting the right keywords, businesses can ensure that their content aligns with user intent, driving organic traffic and conversions. Keyword research related aspects were mentioned in nearly all the analyzed articles, which resulted in a total of ten unique techniques, described in Table 20.

The most frequently mentioned technique in this category is *merging head terms with modifiers and related terms into long-tail keywords with a consistent, scalable pattern*, which is referenced in 26 articles. This is strongly related to *identifying head terms and their variations*, which appeared in 20 references, and *identifying keyword primary and secondary modifiers and related terms*, with 18 references. Head terms are broader search terms with high search volumes, whereas modifiers are words related to the head terms that can be used to create more specific search queries [78]. Modifiers can further be divided into primary modifiers, which create a new category for a search term, and secondary modifiers, which describe the head term [104]. By combining head terms with modifiers, businesses can craft long-tail keywords that align closely with users' search intent. For instance, a head term could be "things to do in" [79], a primary modifier for it could be "Turku", and secondary modifier could be "for free", generating the long-tail keyword "things to do in Turku for free" with a scalable pattern. By changing the primary modifier to represent different locations or adjusting the secondary modifier to vary contexts or specifics, one can generate a vast number of unique keywords. These keywords often have lower competition and higher conversion potential, making them ideal for pSEO campaigns.

Another important technique is *analyzing and prioritizing keywords based on search intent, competition, and search demand, prioritizing low-competition keywords with transactional intent*, which is mentioned in 18 articles. This process helps prioritize keywords that align with queries that provide value for both the customer and the business. It also highlights the importance of targeting low-competition keywords. These keywords do not need to have high search volumes; instead, even modest traffic to each page can accumulate, generating substantial total traffic across a large number of niche query pages.

Utilizing tools and AI for data-driven keyword selection is a technique referenced in 10 articles. The following tools were mentioned in the material, roughly ordered based on

popularity: Google Keyword Planner, Google Search Console, Google Trends, Ahrefs Keywords Explorer, Semrush Keyword Magic Tool, Moz Keyword Explorer, Ubersuggest, Answer the Public, BrightEdge, and SEOmator. It is recommended to use these tools to gather data on search volumes, trends, and competition, which enables data-driven decisions for selecting the most relevant and effective keywords for the programmatic pages.

Less mentioned, but still noteworthy, is *organizing and structuring keywords for management purposes*, which was mentioned in four articles. This practice involves creating logical taxonomies or grouping keywords by search intent, such as informational, transactional, or navigational. This helps manage large sets of keywords and optimize page targeting.

Two other important but less frequently cited techniques are *conducting competitive analysis of search results*, with three references, and *assigning unique keywords to different pages*, with two references. Competitive analysis helps identify gaps in keyword coverage by examining the keywords competitors rank for, while assigning unique keywords to different pages ensures that each page targets a distinct search intent, preventing duplicate content and avoiding competition between the pages, also referred to as keyword cannibalization.

The techniques *using natural language keywords* and *utilizing "Searches related to" in Google Search Console*, had both one reference in the articles. These techniques aim to align keyword strategies with user behavior. By focusing on natural language, which is how people typically phrase queries, pSEO efforts can feel more conversational and user-friendly. Additionally, using related searches helps refine keyword selection and reveals alternative ways users might search for the same topic.

In summary, keyword research is a cornerstone of successful pSEO, as it directly influences the ability to scale content effectively. By focusing on long-tail keywords, businesses can craft precise, high-value search queries that align with user intent, particularly for transactional and commercial searches. The various techniques outlined ensure a well-rounded and data-driven approach to targeting the most relevant and impactful keywords.

Table 20. Conducting Keyword Research for pSEO

Technique	n	References
Merge head terms with modifiers and related terms into long-tail keywords with a consistent, scalable, pattern.	26	[78], [79], [82], [83], [84], [85], [86], [87], [88], [90], [91], [92], [93], [95], [96], [97], [98], [99], [103], [104], [105], [109], [110], [111], [114], [117]
Identify head terms and their variations.	20	[77], [78], [79], [80], [83], [84], [85], [87], [88], [90], [91], [92], [93], [95], [97], [103], [104], [109], [110], [118]
Identify keyword primary and secondary modifiers and related terms.	18	[77], [78], [79], [83], [84], [85], [87], [88], [90], [91], [92], [93], [95], [97], [103], [104], [109], [118]
Analyze and prioritize keywords based on search intent, competition, and search demand, prioritizing low-competition keywords with transactional intent.	18	[78], [80], [81], [82], [84], [90], [91], [92], [95], [96], [99], [101], [103], [106], [108], [109], [110], [113], [117]
Utilize tools and AI for data-driven keyword selection based on search volumes and competition.	10	[85], [86], [87], [88], [90], [91], [92], [97], [104], [106], [109], [114]
Organize and structure keywords for management purposes (lists, clustering, logical taxonomy, grouping by search intent; informational, transactional, navigational).	4	[85], [93], [104], [106]
Do a competitive analysis of search results by searching the targeted keywords in Google, identifying competitors and then analyzing the keywords they rank for.	3	[85], [104], [109]
Assign unique keywords to different pages and ensure that each page targets distinct search intent to avoid internal competition and duplicate content (keyword cannibalization).	2	[98], [107]
Use natural language keywords that mimic how people talk and search.	1	[98]
Utilize “Searches related to” in the bottom of the search page in Google search Console to understand keyword search intent.	1	[85]

Designing and Building Programmatic Pages

Nearly all of the articles include techniques dealing with the design and automated generation of landing pages. The techniques were synthesized into 12 unique subclasses, outlined in

Table 21. These techniques are at the heart of any pSEO strategy, as they allow creation of vast amounts of SEO-optimized pages at scale. A well-thought-out approach to page design ensures that these pages are both structured for optimal UX and search engine visibility. By leveraging automated systems, businesses can generate pages tailored to specific keyword variations while maintaining unique, high-quality content that satisfies user intent.

The most frequently mentioned technique in this category is *designing structured, scalable page templates with placeholders for elements that change between keywords*, which is referenced in 30 articles. These templates serve as the blueprint for programmatic pages, allowing for the dynamic insertion of keyword-specific content, such as product details, pricing, or location. This flexibility ensures that the pages can target a range of different keyword variations while maintaining consistency and scalability across the website.

Closely related is the technique of *generating pages for keyword variations programmatically at scale*, mentioned in 23 articles. This approach involves using the designed templates and integrating them with a database to automatically generate large volumes of pages that target different keyword variations. These pages are created with the help of data-driven systems, ensuring that each page is aligned with its specific keyword while avoiding time-consuming and inefficient manual content creation.

A very important technique is *ensuring that the generated pages are unique*, with a total of 20 references. Since programmatic pages often follow a similar structure, it is crucial to differentiate them to avoid duplicate content issues. This could be achieved by modifying metadata, heading tags, product images, CTAs (Call-To-Action), and other details, and by utilizing user-generated content. This also ensures that each page provides unique value to both users and search engines.

Another key aspect of building effective programmatic pages is *leveraging internal linking* to connect these pages with each other and other pages on the website, as mentioned in 19 articles. This can be achieved through breadcrumbs, related pages, location-based navigation, and key category pages. Internal linking improves the overall site structure, helps with indexation by search engines, and guides users through the site, increasing engagement and improving UX.

A frequently mentioned technique strongly related to the automated generation of programmatic pages is *building a well-structured database with high-quality data*, which is

mentioned in 18 references. This database is the backbone of the programmatic pages, storing and managing the data used to populate the templates. A well-organized database ensures that the right information is consistently displayed across all generated pages. It also enables easily updating and generating new pages as new data becomes available.

An important technique mentioned in 15 references is *the optimization of programmatically generated pages for both SEO and UX*. This includes optimizing all the SEO elements identified in chapter 5.3, including On-Page SEO, Technical SEO, and UX aspects. pSEO is essentially merely a technique to efficiently generate a large volume of search engine optimized pages, therefore highlighting the importance of applying traditional SEO techniques on the generated pages.

Related to building the database for the content, with eight references in the articles, is the technique of *utilizing proprietary, public, user-generated, and scraped data* for content generation. This technique essentially helps highlight sources for the data to utilize in the programmatic pages to enable providing unique and relevant content on each page.

Some techniques, though less frequently mentioned, are still essential for maintaining quality and compliance. *Avoiding doorway pages* was mentioned in seven articles. Doorway pages are pages designed to rank high in search results, but instead of providing value directly, redirect users to other pages. This is considered a harmful practice by Google and therefore should be avoided. *Adding unique visuals* like charts, tables, interactive elements such as filters or calculators and a clear CTA, with 5 mentions, is a technique that can significantly improve user engagement and dwell time, which are important ranking factors. *Keeping URL slugs short and focused on primary keywords*, with four references, and *automating schema markup generation*, with three references, help ensure that pages are optimized for both search engines and UX. Short, descriptive URLs are more user-friendly and help search engines understand the focus of the page, while schema markup provides additional context for search engines, improving visibility in search results and increasing the chances of the pages being displayed in rich snippets.

Designing and building programmatic pages requires carful planning, data management, and optimization to ensure scalability, uniqueness, and relevance. By following the outlined techniques, businesses can create vast numbers of pages tailored to user intent, optimized for search engines, and designed for seamless user experience. These pages form the foundation of a successful pSEO campaign.

Table 21. Designing and Building Programmatic Pages

Technique	n	References
Design structured, scalable page templates with placeholders for elements that change between keywords.	30	[77], [78], [80], [81], [82], [83], [84], [86], [87], [88], [89], [91], [92], [95], [96], [97], [99], [101], [103], [104], [105], [106], [107], [108], [109], [111], [113], [115], [117], [118]
Generate pages for keyword variations programmatically at scale with data and the templates.	23	[77], [78], [79], [80], [82], [83], [85], [86], [90], [95], [96], [97], [99], [101], [103], [105], [106], [108], [109], [110], [113], [115], [118]
Ensure that the generated pages are unique by modifying metadata, heading tags, product images, CTAs, and other details, and by utilizing user-generated content.	20	[78], [84], [86], [88], [89], [90], [91], [93], [95], [98], [99], [101], [103], [104], [105], [107], [108], [109], [110], [115]
Leverage internal linking to connect the programmatically generated pages with each other and other pages on your website: utilize breadcrumbs, related pages, location-based navigation, key category pages, CTAs, etc.	19	[77], [78], [79], [80], [81], [83], [84], [88], [90], [93], [95], [98], [103], [105], [106], [107], [109], [110], [113]
Build a well-structured database with high-quality data to store and manage the data used in the pages.	18	[77], [80], [81], [83], [86], [87], [88], [90], [91], [92], [93], [95], [97], [99], [101], [106], [107], [113]
Ensure that programmatically generated pages are optimized for SEO and UX.	15	[77], [80], [83], [86], [88], [90], [97], [99], [101], [105], [107], [109], [111], [113], [115]
Utilize proprietary, public, user-generated, and scraped data for content generation.	8	[86], [88], [93], [96], [97], [99], [101], [109]
Avoid doorway pages, pages designed to redirect users to a different page.	7	[78], [79], [80], [83], [85], [86], [104]
Add unique visuals like charts and tables, interactive elements such as filters or calculators, and a clear CTA to improve engagement, dwell time, and user retention.	5	[92], [103], [107], [109], [117]
Keep the URL-slugs short and focused on the primary keywords.	4	[95], [105], [109], [115]
Automate generation of schema markup.	3	[106], [113], [115]
Test and refine page templates on a small scale before scaling	2	[89], [106]

Creating the Content for the Pages

Creating high-quality content for the programmatic pages is essential to ensure that they provide value to the users. Many of the articles mentioned techniques related to content creation, which resulted in seven unique techniques, as presented in Table 22.

The most commonly mentioned technique in this category is *ensuring that the pages directly address search intent*, with 17 references, which is vital for programmatic pages to be useful

and relevant to users. Pages must answer questions, solve problems, or provide the information users are looking for.

Closely related to this is *ensuring that the generated pages provide value*, instead of just altering keywords, which is mentioned in 15 articles. This also means avoiding thin, low-quality content by either improving it, consolidating with other content, or by removing such pages altogether.

An important aspect is the *utilization of AI for generating high-quality content*, which was mentioned in nine articles, and *to improve content with targeted keywords, readability, and voice search optimization*, which was mentioned in 5 articles. The articles recommended utilizing AI-powered tools, such as Jasper, WordLift, and ChatGPT for automating content generation at scale. They also highlighted how manual refinement is still necessary to ensure the quality, relevance, and uniqueness of the generated content. AI tools are a great way to produce drafts and base content, while human oversight is essential to ensure alignment with the brand's voice and quality of the content. AI tools can fine-tune content for better SEO, help with local SEO by including location-based keywords, and improve content's performance in voice search by making it more conversational and natural.

A more specialized but useful technique mentioned in one article is *hiring freelance writers to create unique introductions for each individual page*. This helps provide more personalized touch to the content, making each page feel less automated and more customized for the specific keyword and user intent. However, it requires more manual work for generating the pages, making it unsuitable for some scenarios.

Additional techniques mentioned in one article include *adding external links to additional resources to improve the content's quality, relevance, authority, and credibility*, and *personalizing content based on industry and buyer personas*. These techniques are useful for further enhancing the user experience and increasing the perceived value of the page for the target audience.

In summary, creating content for pSEO pages requires more than inserting keywords into templates. It requires addressing user intent and providing valuable and engaging content. AI tools can be utilized for scaling content generation and refining the pages for quality. These techniques ensure that the programmatic pages are optimized for search engines and provide real value to users.

Table 22. Creating the Content for the Pages

Technique	n	References
Ensure that the pages directly address search intent (answers users' questions and solves their problems)	17	[78], [79], [80], [81], [82], [84], [85], [90], [93], [99], [99], [101], [104], [107], [108], [111], [117]
Ensure that the generated pages provide value instead of only altering keywords. Improve, consolidate, or remove thin, low-quality content to form these pages.	15	[77], [79], [84], [85], [86], [91], [93], [95], [96], [98], [104], [107], [109], [112], [117]
Use AI tools (jasper, WordLift, ChatGPT) to generate high-quality content, but manually refine AI-written text.	9	[80], [81], [87], [92], [95], [97], [106], [108], [114]
Use AI to improve content with keywords, make it easier to read, work better with voice search, help with local SEO, translate, and improve on-page SEO.	5	[87], [90], [105] [106], [114]
Hire freelance writers to create unique introductions for each individual page	1	[88]
Add external links to additional resources to improve content quality, relevancy, authority and credibility	1	[84]
Personalize content based on industry and buyer personas to make it more relevant and engaging	1	[105]

Managing Sitemaps

One of the common problems with programmatically generated pages is that they are not getting indexed by search engines. An essential part of managing a large-scale pSEO campaign is creating and maintaining sitemaps that help search engines crawl and index programmatic pages effectively. Techniques related to managing sitemaps were mentioned in some of the articles, which resulted in 4 unique techniques outlined in Table 23. A well-organized sitemap ensures that search engines understand the structure of the site and can easily discover new pages, improving their visibility in search results.

The most frequently mentioned technique in this category is *programmatically generating sitemaps for each directory, organizing pages into logical categories or themes and prioritizing the most important pages* mentioned in 5 articles. This technique ensures that the sitemaps contain all the programmatically generated pages. A logical, well-organized sitemap helps search engines crawl more efficiently, which is particularly important for large-scale websites with thousands of pages. Prioritizing key pages ensures that important content is indexed faster and more thoroughly.

Submitting generated URLs for crawling via Google Search Console, with 3 references, is another important step. This process accelerates the indexing of new pages, ensuring that they are discovered and appear in search results as quickly as possible. By submitting the sitemap

directly to Google, website owners can monitor their pages' crawl status and troubleshoot any issues that may arise. One of the articles recommended *forcing multiple crawls of each sitemap to ensure timely discovery and indexing of pages*. This technique may further speed up the indexing process.

For very large sites, *creating additional sitemaps* may be necessary, as mentioned in 2 articles, especially when the number of URLs exceeds the maximum limit of 50,000 URLs per sitemap. This technique ensures that all pages are included in the indexing process, regardless of the site's size. Additionally, creating separate sitemaps for different content types or themes can improve crawl efficiency. In general, managing sitemaps for pSEO is crucial for ensuring that programmatic pages are efficiently crawled and indexed by search engines.

Table 23. Techniques for Managing Sitemaps

Technique	n	References
Programmatically generate sitemaps for each directory, organizing pages into logical categories or themes and prioritizing the most important pages	5	[83], [93], [98], [107], [109]
Submit generated URLs for crawling via Google Search Console to accelerate indexing	3	[87], [88], [107]
Create additional sitemaps as needed to enable scaling beyond the maximum of 50,000 URLs per sitemap	2	[88], [93]
Force multiple crawls of each sitemap to ensure timely discovery and indexing of pages	1	[83]

Maintaining and Improving the Pages

A theme that appeared in many articles was the maintenance and refinement of the generated pages. After the pages have been created and indexed, it is essential to maintain and continuously improve them to sustain long-term SEO performance. This involves tracking the performance of the pages, refreshing content, and ensuring that the pages stay relevant and useful to the users. The articles mentioned five unique techniques related to maintaining the pages, listed in Table 24.

The most frequently mentioned technique in this category is *tracking performance using web analytics Google Search Console, and heatmaps, and refining the pages accordingly*, with nine references. Monitoring key metrics such as traffic, bounce rate, user engagement, and conversions allows businesses to identify underperforming pages and take steps to optimize them.

Regularly updating and refreshing the content is another crucial technique mentioned in three articles. This technique ensures that the pages remain relevant and provide up-to-date information, which is particularly important for industries where the data changes frequently. Regular updates also signal to search engines that the page is maintained and authoritative, which improves its chances of ranking high over time.

The technique of *implementing human reviews and continuously improving the system*, mentioned in three articles, is important for maintaining quality and ensuring relevance of the pages. While automated systems can generate and update content at scale, human oversight ensures that the content remains high-quality, accurate, and relevant. By conducting periodic reviews, businesses can ensure that the content aligns with the latest trends and user expectations.

Conducting site audits to identify technical issues, with two references, is a technique that helps businesses identify and resolve technical SEO issues such as broken links and slow page load times. For this, there are tools like Google Search Console, and Screaming Frog. One article mentioned the technique of *setting up automated reports to monitor keyword performance*, which enables optimizing content strategy.

Table 24. Techniques for Maintaining and Improving the Pages

Technique	n	References
Track performance using web analytics, Google Search Console, and heatmaps and refine the pages accordingly	9	[77], [80], [81], [90], [92], [105], [109], [110], [113]
Regularly update and refresh the content	3	[81], [84], [110]
Implement human reviews and continuously improve the system to ensure quality and relevance	3	[81], [110], [114]
Conduct site audits to identify technical issues, using tools like Google Search Console, and Screaming Frog	2	[92], [114]
Set up automated reports to monitor keyword performance and optimize content strategy	1	[113]

Acquiring Backlinks

Backlinks signal to search engines that a page is authoritative and trustworthy, helping to improve its ranking in search results. Acquiring high-quality backlinks is a key component of any successful SEO strategy, which is why it is important for pSEO as well. Regardless, only a few of the articles mentioned backlinks, which might be because it is a key part of traditional SEO anyway. Three unique techniques for acquiring backlinks were identified from the articles, outlined in Table 25.

Three articles mention *developing scalable backlink acquisition strategies*, as a general technique. This involves creating systems and processes that can generate backlinks efficiently, without relying on manual outreach or tactics that are difficult to scale. One article presents the technique of *using ego-bait and embed codes to generate backlinks*. This involves creating shareable content, such as badges or visual rewards, that other businesses or websites can embed on their own pages. This method incentivizes other sites to link back to the programmatic pages, therefore creatively increasing the number of backlinks. The technique *creating viral content to attract organic backlinks*, with one reference, is also an effective way to naturally acquire backlinks. By producing highly shareable and engaging content, businesses can encourage other websites to link to their pages. In general, all of the techniques related to backlinks, discussed in chapter 5.3.2 on Off-Page SEO, apply for pSEO as well.

Table 25. Techniques for Acquiring Backlinks

Technique	**n**	**References**
Develop scalable backlink acquisition strategies	3	[85], [88], [98]
Use ego-bait and embed codes to generate backlinks	1	[85]
Create viral content to attract organic backlinks	1	[85]

6.4 Practical Considerations

Building on the qualitative content analysis on pSEO techniques, this section focuses on their practical application. RQ2, “How to utilize Programmatic SEO to improve visibility of a web application in Google Search results”, is answered here concretely in subchapter 6.4.1, with additional insights provided in 6.4.2. While pSEO offers significant advantages—such as scalability, efficiency, and improved search visibility—its success depends on strategic execution. This chapter presents a structured approach for conducting pSEO, explores its optimal use cases, and address potential challenges to ensure effective deployment.

6.4.1 How to Conduct Programmatic SEO?

This section outlines the practical seven steps required to execute Programmatic SEO effectively. The steps were defined based on the results from the qualitative content analysis, forming a structured process for implementing pSEO techniques systematically. Here are the steps:

1. Develop a Programmatic SEO Strategy: Start with in-depth niche, competitor, and audience research to identify opportunities and set goals. Align content with high-conversion queries and establish a solid SEO foundation before scaling.
2. Conduct Keyword Research: Identify head terms and modifiers to generate scalable long-tail keyword variations. Prioritize keywords based on intent, low competition, and high search volume while leveraging AI-powered tools for data-driven insights.
3. Design and Build Programmatic Pages: Create structured templates with placeholders for dynamic content. Ensure uniqueness by modifying metadata, headings, and product descriptions while integrating internal linking.
4. Create High-Quality Content: Ensure content aligns with search intent and provides real value. Utilize AI tools for scalable content generation but refine manually to maintain quality and relevance.
5. Create and Manage Sitemaps: Generate sitemaps programmatically and submit them via Google Search Console. Use additional sitemaps if necessary and trigger multiple crawls to improve indexing.
6. Acquire Backlinks for Authority: Develop scalable backlink strategies. Leverage ego-bait and embed codes and create shareable content to attract organic links.
7. Maintain and Improve Pages: Track performance with analytics tools and refine underperforming pages. Regularly update content, conduct technical SEO audits, and analyze user behavior to sustain relevance.

6.4.2 When to Leverage Programmatic SEO?

Programmatic SEO is particularly beneficial for businesses that require scalable content production while maintaining cost efficiency and consistency. It allows for quick and easy scaling, enabling businesses to rank for hundreds of keywords with the effort of one [88]. With pSEO, organizations can generate large volumes of content efficiently [77], [79], improve search visibility by targeting long-tail keywords [83], and gain competitive insights through data-driven optimization [87]. Industries with extensive product catalogs or multi-location services, such as e-commerce, travel, and SaaS platforms, generally benefit the most from pSEO [77].

Programmatic SEO is widely utilized across various industries to generate scalable and data-driven content. Travel websites like TripAdvisor create unique pages for every city, listing hotels, restaurants, and attractions, while e-commerce platforms such as Amazon dynamically generate product pages for every variation and category to capture a broad range of search queries [77]. Similarly, SaaS companies leverage pSEO for integration pages, as seen in Zapier's extensive library of "How to connect [app] and [app] pages [78]. Real estate platforms like Zillow automate pages for property listings based on location, and design tools like Canva provide dynamically generated templates for different graphic formats [92]. By applying similar methodologies, businesses operating across multiple locations, selling diverse products, or offering extensive services can harness pSEO to improve search visibility. Additionally, pSEO is useful for generating competitor and alternative comparison pages, which helps businesses capture more search intent traffic [118].

Despite its advantages, pSEO poses challenges if it is executed poorly. Risks include generating thin, duplicate, or low-quality content [88], high upfront technical requirements and implementation costs [87], and indexing difficulties that may lead to search engine penalties [83]. Programmatic SEO is likely not the optimal solution for providing creative, in-depth content [86]. Ensuring high content quality and proper execution is crucial to avoiding these pitfalls.

The rise of AI and automation has made pSEO more accessible and efficient, allowing businesses to quickly analyze large datasets, identify patterns and optimize content strategies with greater precision [86], [114]. AI-powered tools can enhance keyword targeting based on real-time search trends, automate content creation, generate meta tags, and streamline link-building efforts, significantly improving scalability [114]. However, as generative AI continues to evolve, uncertainty remains about its long-term impact on SEO, with concerns that pSEO might become less and less valuable over time [91]. While AI-driven pSEO offers substantial benefits, maintaining oversight is essential to ensure content quality, avoid algorithmic penalties, and adapt to the changing search landscape [86], [91]. Despite potential challenges, pSEO remains a valuable strategy for businesses seeking scalable, data-driven content production to dominate search rankings.

7 Case Study: Search Engine Optimization for a Firewood Marketplace App

In this chapter, a case study is conducted on a firewood marketplace app that is currently under development. The goal of this study is to apply the SEO best practices identified in chapter 5 to a real-world application, demonstrating how these techniques can be practically integrated into a modern app. The focus is on implementing technical SEO and on-page SEO strategies and measuring SEO. After applying the techniques, SEO performance is evaluated using audit tools to assess the practical effectiveness of the recommendations. Additionally, the chapter explores how pSEO can be utilized in practice. It is important to note that fully measuring the long-term impact of these SEO techniques would require a longer time period than is available for this study. This chapter demonstrates how SEO best practices and pSEO can be applied to the firewood marketplace app, providing immediate feedback through SEO audit tools.

7.1 Firewood Marketplace App Introduction

The firewood marketplace app is a platform designed to connect buyers and sellers of firewood. The application helps sellers reach buyers, while helping buyers find competitive firewood deals. Buyers can request offers for firewood by submitting a multi-step form detailing their firewood needs. This quotation request is then delivered to all registered sellers in the buyer's area who meet the specified criteria, allowing them to submit offers. Buyers can review these offers and accept or reject them. Upon accepting an offer, the buyer receives the seller's contact information, which enables them to contact the seller to finish the deal outside of the application.

Currently, the application is under development, with a nearly completed minimum viable product that includes the essential features necessary for its functionality. From a business perspective, the application will be offered free to all users during the launch phase, with the primary focus on building a strong user base. Once the platform has a sufficient number of users, it will provide significant value to sellers, which will then allow for monetization through annual seller subscriptions.

The application has been designed with internationalization in mind, ensuring it can be easily adapted for use in different countries and regions. The application will be launched in Finland, targeting a relatively small geographic area. However, the application is built to

scale, with plans to expand to larger areas and other countries in the future. To support this, the platform already supports multiple language versions, with Finnish and English already available. Additionally, the application supports both metric and imperial measurement systems, as well as multiple currencies, including the Euro and USD, to enable scaling across different regions.

SEO is a critical component for the application, as it provides an effective and cost-efficient method for attracting organic traffic without the need for significant financial investment in paid advertising. Given that the application is still in its early stages and does not generate revenue until it is fully monetized, SEO becomes especially important for building visibility and acquiring users. By optimizing the platform for search engines, the application can attract potential buyers who are actively searching for firewood deals. This, in turn, increases the platform's value for sellers, encouraging them to register on the platform. Effective SEO strategies will help establish a strong online presence, ensuring that the application remains competitive in a crowded market while keeping acquisition costs low during its initial growth phase.

The platform is implemented as a web application, utilizing Next.js as the full-stack framework, Neon Serverless Postgres as the database provider, and Vercel for hosting. These technologies were carefully selected for their optimization, performance, scalability, and seamless integration.

Next.js, is a highly popular full stack React framework, known for its strong SEO capabilities and performance optimization. It was chosen primarily for its ability to improve SEO through its SSG approach and other SEO optimizations. Next.js also supports SSR and CSR, offering a flexible approach that should ensure both fast page loads and smooth transitions to dynamic interactive content. The introduction of Server Components in Next.js further optimizes server-side processing, making it more efficient and reducing the load on the client-side. [121] Kowalczyk & T. Szandala [14] showed in their study that even without additional optimizations, applications built with Next.js outperformed traditional React applications in SEO performance, particularly during the initial load phase, highlighting the benefits of SSG in delivering fast and SEO-friendly pages.

Internationalization was implemented using the next-intl library, which provides a streamlined approach for adding translation and language support to the application. This is crucial for the planned expansion into different regions, as it facilitates the localization of the user

experience by supporting multiple languages and formats. next-intl makes it easy to translate all textual content, including URL pathnames, while also localizing other elements such as numbers and dates, ensuring a seamless experience for users across different locales.

7.2 SEO Implementation

As described in chapter 6, it is important to establish a strong foundation for SEO before conducting Programmatic SEO. This foundation was built by applying the SEO techniques identified in chapter 5 that are relevant during the development phase. These techniques were adapted to the technical context of a modern web application developed with Next.js. This subchapter presents an overview of the implemented techniques with concrete examples from the application.

7.2.1 Server-Side Rendering, Static Site Generation, Performance Optimization

The Technical SEO recommendations for architecture include utilizing SSR, implementing isomorphic JavaScript with prerendering, and minimizing JavaScript for faster load times. Next.js as the framework inherently supports and provides these features. SSG is leveraged for all the pages where it is applicable, improving load times and producing SEO-friendly markup, while SSR and CSR are used where dynamic content or authentication is required. To enable SSG for localized pages, the generateStaticParams function in Next.js is used to pre-render pages for all supported locales (see Listing 1).

Listing 1. Enabling SSG in localized pages

```
export function generateStaticParams() {
    return routing.locales.map((locale) => ({ locale }));
}
```

7.2.2 Domain, HTTPS, page URLS

The Technical SEO recommendations include choosing a reputable TLD and maintaining domain age. The On-Page SEO recommendations include using a domain name that aligns with the brand or includes relevant keywords, ideally keeping it under 15 characters and avoiding hyphens. The domain selected for the project is “polttopuutori.fi”, which is essentially the Finnish brand name accompanied by the trusted Finnish TLD “.fi”. This domain clearly follows all the recommendations. The brand name itself also incorporates

relevant keywords “polttopuu” (“firewood” in Finnish) and “tori” (“market” in Finnish), which directly describe the purpose of the application. When localizing the application to other countries, it may be beneficial to adopt a different brand name and domain, as the Finnish terms are not meaningful in non-Finnish-speaking markets.

Vercel as the hosting platform automatically provisions SSL certificates, ensuring that the site is served over HTTPS. Therefore, the Technical SEO recommendation to use HTTPS is automatically followed when using Vercel.

The On-Page SEO recommendations state that URLs should be short, have a logical structure, include relevant keywords, use hyphens to separate words, and prefer static URLs. Since next-intl is used to translate URL pathnames, they can simultaneously be optimized for SEO without worrying about the underlying technical routing structure. For example, to optimize the sign in pages for SEO, the route “/auth/sign-in/email” for signing in with email was rewritten in English as “/sign-in-with-email” and in Finnish as “/kirjaudu-sahkopostiosoitteella”.

7.2.3 Page Titles and Meta Descriptions

The On-Page SEO recommendations advise defining unique and relevant page titles for each page, incorporating the main keyword and brand name when applicable and keeping it between 40-65 characters long while avoiding stop words. Similarly, it is recommended to define a unique meta description for each page while including relevant keywords, minimizing the use of stop words, keeping its length between 125 and 160 characters, and including emojis or a call to action.

Since the application has multiple language versions, the page titles and meta descriptions are translated accordingly. In Next.js, these can be defined in special layout and page files. The pattern used in the firewood marketplace app utilizes Next.js’s generateMetadata function to define, in the root layout, a default title that includes the brand name and a title template that appends the brand name to individual page titles, as recommended (see Listing 2). A default description is also provided. These texts are translated using next-intl and the getTranslations function. While default titles and descriptions help ensure no page is missing basic metadata, they can result in multiple pages with non-unique values. Therefore, it is important to ensure that all indexed pages are assigned custom titles and descriptions. Providing fallback values still makes sense to avoid metadata gaps.

Listing 2. Defining metadata in Next.js using the generateMetadata function

```
export async function generateMetadata({
  params,
}: {
  params: Promise<{ locale: Locale }>;
}): Promise<Metadata> {
  const { locale } = await params;
  const t = await getTranslations({ locale,namespace: “metadata” )};

  return {
    title: {
      default: t(“page-titles.default”),
      template: `%s | ${t(“page-titles.default”)}`,
    },
    description: t(“page-descriptions.default”),
  };
}
```

For example, following the recommendations, a suitable title and description for the homepage could be:

Title: “The Easiest Way to Buy and Sell Firewood | Polttopuutori”

Description: “Find trusted local firewood sellers or start selling firewood online today. No fees, no hassle – a free firewood marketplace for buyers and sellers”.

Both the title and description are relevant to the content, include the keyword “firewood”, and adhere to the recommended length limits. The title incorporates the brand name, while the description includes a clear call to action.

7.2.4 Heading Tags and Semantic HTML

On-Page SEO recommendations include the use of semantic HTML and heading tags <h1> to <h6> correctly in hierarchical order, ensuring that each page has a single <h1> with relevant keywords. Semantic elements such as <main>, <section>, <nav>, and <ul> are utilized throughout the application. Especially the pages that are important for SEO, such as the homepage (see Listing 3), are carefully structured using semantic HTML, and they include a well-defined <h1> tag containing relevant keywords. Careful attention is also put into ensuring that the heading tags are used in hierarchical order.

Listing 3.TSX markup of the homepage

```
<>
  <main className="mx-auto w-full max-w-screen-xl p-3">
    <section className="my-5 flex w-full gap-3">
      <div className="ml-0 flex w-full max-w-screen-sm flex-col gap-3">
        <h1 className="h1">{t("home-page.hero-title")}</h1>
          <p className="leading-relaxed text-foreground-muted">
            {t("home-page.hero-subheadline")}
          </p>
          <div className="mt-2 flex gap-2">
            <Button asChild variant="cta" size="lg">
              <Link href="/request-offers/firewood">
                {t("home-page.Request Firewood Offers")}
              </Link>
            </Button>

            <Button asChild variant="outline" size="lg">
            <Link href="/dashboard">
              {t("home-page.Start Selling")}
            </Link>
          </Button>
        </div>
      </div>
    </section>
  </main>
  <script
    type="application/ld+json"
    dangerouslySetInnerHTML={{ __html: webPageJsonLd }}
  />
  <script
    type="application/ld+json"
    dangerouslySetInnerHTML={{ __html: requestOffersJsonLd }}
  />
  <script
    type="application/ld+json"
    dangerouslySetInnerHTML={{ __html: startSellingJsonLd }}
  />
</>
```

The Technical SEO recommendations also highlight the importance of setting the correct lang attribute on the <html> element based on the language of the page. This attribute is dynamically set in the Next.js root layout component using the next-intl library to determine the user's current locale (see Listing 4).

Listing 4. Defining the lang attribute dynamically based on locale

```
export default async function RootLayout({
  children,
  params,
}: Readonly<{
  children: React.ReactNode;
  params: Promise<{ locale: Locale }>;
>) {
  const [{ locale }, messages] = await Promise.all([
    params, getMessages()
  ]);

  return (
    <html lang={locale} suppressHydrationWarning>
      <body
        …
```

7.2.5 Internal Linking

The Technical SEO recommendations include ensuring that internal links are structured logically, using descriptive anchor text, and avoiding excessive links. The application is designed to have a responsive navigation bar with all the main links, including the authentication buttons. As a standard practice, a footer is also included to display relevant links. However, as the application is still under development, most pages have not yet been created. These pages will be created and linked as development progresses.

7.2.6 Mobile Optimization

The Technical SEO recommendations include ensuring mobile-friendly design and the implementation of AMP pages. The application is fully responsive and optimized for mobile devices. Using Next.js with its performance optimizations significantly benefits mobile users. While AMP page implementation is recommended, it has not been applied to the application at this stage. Landing pages could potentially be converted into AMP pages, but they already achieve great performance with SSG. Implementing AMP would require manually creating the pages without next-intl and existing UI components, as AMP pages do not allow running custom JS code. As a result, AMP would provide only marginal benefits in specific cases, requiring significant effort for relatively little return.

7.2.7 Image Optimization

The On Page SEO recommendations include optimizing image attributes with relevant keywords. Key attributes to optimize are alt text, title, caption and filename. Additionally, image optimization involves compressing images, using the WebP format, employing responsive images, and enabling lazy loading for off-screen images. Next.js provides an <Image> component, which directly addresses several key image optimization concerns [122]: it optimizes image sizes, serving correctly sized images for each device, uses modern image formats, such as WebP, prevents layout shift during image loading, and improves page load speed by lazy loading images.

7.2.8 Social Media Sharing, Favicon

Next.js also allows generating Open Graph (OG) images using special opengraph-image.tsx files, improving shareability on social platforms. The favicon can be generated with a special icon.tsx file, or by directly providing the favicon.ico file in the app directory. Since the brand does not have a logo yet, the icon is generated with the initial letter “P” of the brand name.

7.2.9 Robots and Sitemap

The Technical SEO recommendations include creating a robots.txt file to guide search engine bots on which pages to crawl. In this case, it is unnecessary for search engine bots to crawl routes that require authentication or that otherwise provide no value to search engines. In the firewood marketplace app, the “/dashboard” routes require authentication, so such routes along with all their localized versions are disallowed in robots.txt. Similarly, “/api/” routes provide no value to search engines and are also disallowed. Next.js allows generating the robots.txt via code using a special “robots.ts” file. This file allows programmatically disallowing the localized versions of the pages. The resulting robots.txt file is shown in Listing 5.

Listing 5. Generated robots.txt file

```
User-Agent: *
Allow: /
Disallow: /api/
Disallow: /dashboard
Disallow: /paneeli
Disallow: /fi/dashboard
Disallow: /fi/paneeli
Disallow: /en/dashboard
Disallow: /en/paneeli

Sitemap: https://dev.polttopuutori.fi/sitemap.xml
```

The firewood marketplace app contains various types of pages, including landing pages (such as the home page), pages for requesting offers, dashboard pages, and authentication pages. Out of these, only the landing pages and the main authentication pages should be indexed by search engines, as they are the primary entry points to the application that do not require being authenticated. Therefore, additional metadata with noindex and nofollow directives for robots has been implemented in the top-level layouts of the other route groups, using the Next.js's metadata object (see Listing 6). This prevents these pages from being indexed while still allowing search engines to follow links, supporting them in forming a comprehensive understanding of the site structure.

Listing 6. Defining the robots meta tag in Next.js

```
export const metadata: Metadata = {
  robots: {
    index: false,
    follow: true,
  },
};
```

The robots.txt file also includes a reference to the XML sitemap. This follows the Technical SEO recommendations to create and regularly update an XML sitemap to ensure that important pages are properly crawled. In Next.js, the sitemap can be generated using a special sitemap.ts file placed in the app directory. The sitemap also defines alternate language versions using the "alternates" tag. These are generated programmatically to ensure that all localized routes are reflected in the sitemap. As development continues, the sitemap will be updated to include all landing pages, including those generated from Programmatic SEO. The file creating the sitemap and the generated sitemap are presented in Listing 7 and Listing 8.

Listing 7. Code for generating the sitemap

```
export default function sitemap(): MetadataRoute.Sitemap {
  return [
    {
      url: getDefaultLocalePath(”/”),
      lastModified: new Date(”2025-04-28”),
      changeFrequency: ”weekly”,
      priority: 1,
      alternates: {
        languages: generateAlternateLanguagesFromRoute(”/”),
      },
    },
    {
      url: getDefaultLocalePath(”/auth/sign-in”),
      lastModified: new Date(”2025-04-28”),
      changeFrequency: ”monthly”,
      priority: 0.3,
      alternates: {
        languages: generateAlternateLanguagesFromRoute(”/auth/sign-in”),
      },
    },
    {
      url: getDefaultLocalePath(”/auth/register”),
      lastModified: new Date(”2025-04-28”),
      changeFrequency: ”monthly”,
      priority: 0.3,
      alternates: {
        languages: generateAlternateLanguagesFromRoute(”/auth/register”),
      },
    },
  ];
}
```

Listing 8. The generated sitemap

```
<urlset xmlns="http://www.sitemaps.org/schemas/sitemap/0.9"
  xmlns:xhtml="http://www.w3.org/1999/xhtml">
  <url>
    <loc>https://dev.polttopuutori.fi</loc>
    <xhtml:link rel="alternate" hreflang="fi"
      href="https://dev.polttopuutori.fi" />
    <xhtml:link rel="alternate" hreflang="en"
      href="https://dev.polttopuutori.fi/en" />
    <xhtml:link rel="alternate" hreflang="x-default"
      href="https://dev.polttopuutori.fi/en" />
    <lastmod>2025-04-28T00:00:00.000Z</lastmod>
    <changefreq>weekly</changefreq>
    <priority>1</priority>
  </url>
  <url>
    <loc>https://dev.polttopuutori.fi/auth/sign-in</loc>
    <xhtml:link rel="alternate" hreflang="fi"
      href="https://dev.polttopuutori.fi/auth/sign-in" />
    <xhtml:link rel="alternate" hreflang="en"
      href="https://dev.polttopuutori.fi/en/auth/sign-in" />
    <xhtml:link rel="alternate" hreflang="x-default"
      href="https://dev.polttopuutori.fi/en/auth/sign-in" />
    <lastmod>2025-04-28T00:00:00.000Z</lastmod>
    <changefreq>monthly</changefreq>
    <priority>0.3</priority>
  </url>
```

```
    <url>
      <loc>https://dev.polttopuutori.fi/rekisteroidy</loc>
      <xhtml:link rel="alternate" hreflang="fi"
        href="https://dev.polttopuutori.fi/rekisteroidy" />
      <xhtml:link rel="alternate" hreflang="en"
        href="https://dev.polttopuutori.fi/en/register" />
      <xhtml:link rel="alternate" hreflang="x-default"
        href="https://dev.polttopuutori.fi/en/register" />
      <lastmod>2025-04-28T00:00:00.000Z</lastmod>
      <changefreq>monthly</changefreq>
      <priority>0.3</priority>
    </url>
  </urlset>
```

7.2.10 Schema Markup

The Technical SEO recommendations include implementing schema markup to make pages eligible for rich search results and to help search engines better understand the page content. JSON-LD schema markup was implemented for the homepage, utilizing the schema-dts npm package to add TypeScript types for the definitions. The markup includes a WebPage type for the page itself; an Offer type (see Listing 9) to describe the primary function of the application—requesting firewood offers; and an Action type for the secondary function of becoming a seller. This structured data was added to the home page inside a <script> tag with type “application/ld+json” (see Listing 3), as recommended in the Next.js documentation [123]. The correctness of the markup was verified using Google’s Rich Results Test tool [124].

Listing 9. JSON-LD schema markup for the request offers service

```
const requestOffersJsonLd = JsonLd<Offer>({
  "@context": "https://schema.org",
  "@type": "Offer",
  url: `${env.NEXT_PUBLIC_BASE_URL}/request-offers/firewood`,
  name: t("home-page.Request Firewood Offers"),
  description: t("home-page.request-offers-description"),
  price: t("home-page.request-offers-service-price"),
  availability: "https://schema.org/InStock",
  eligibleRegion: [
    {
      "@type": "Place",
      name: "FI",
    },
    {
      "@type": "Place",
      name: "US",
    },
  ],
  itemOffered: {
    "@type": "Service",
    serviceType: t("home-page.request-offers-service-type"),
    provider: {
      "@type": "Organization",
      name: t("company.name"),
    },
  },
});
```

7.3 Evaluation of SEO Performance

After implementing various on-page and technical SEO improvements in the firewood marketplace app, it is essential to evaluate their effectiveness using appropriate tools and metrics. To carry out the evaluation, two audit tools were used: Semrush Site Audit and Ahrefs Site Audit. Based on the literature review in chapter 5, those are some of the most advanced and popular tools. Additionally, to fully address RQ4, “How can SEO performance of a web application be measured using Google’s tools, and how can these measurements be used to improve SEO in a deployed application?”, Google Search Console, Google Page Speed Insights, and Google Analytics were also examined. The tests were conducted on a preview deployment on Vercel with the custom domain dev.polttopuutori.fi.

7.3.1 Semrush Site Audit

Semrush is widely recognized as one of the most advanced and comprehensive SEO tools, as supported by the literature review in chapter 5. The audit focuses on numerous SEO factors, including crawlability, page performance, internal linking, HTTPS usage, metadata, markup,

and more. It assigns a Site Health Score, which is calculated based on the number and severity of errors and warnings detected across the site. A higher score reflects fewer SEO issues, suggesting better optimization and overall user experience. Semrush also benchmarks the score against industry averages to provide contextual insight.

The audit was conducted using primarily default settings. The scope was set to the main domain dev.polttopuutori.fi, with subdomains included in the crawl. The list of pages to audit was based on the site's robots.txt and sitemap. Google Analytics was not connected, and the page limit was set to 100, which is the default cap for the free plan. The user agent was configured as SiteAuditBot (Mobile), reflecting mobile-first indexing practices. JS rendering was disabled due to restrictions of the free trial version, which may slightly limit the depth of analysis for JS-heavy content.

The resulting Site Health Score was 97%, indicating a strong technical foundation. The only identified issues were low word count, low text-to-HTML ratio, and pages with only one internal link. These minor issues are expected, as the application is still in development and lacks content and several pages. Importantly, the site scored 100% for Crawlability, HTTPS, Site Performance, and Markup, showing no critical SEO blockers in those areas. Image 1 presents a screenshot of the overview section of the results.

However, one unexpected result was a Core Web Vitals score of 0%, meaning that no page received good results in the Core Web Vitals. The reason for this was the LCP value of 4.24 seconds, which is categorized as Poor. In contrast, the TBT was good at 246 ms, and the CLS was a perfect 0.000. The poor LCP suggests room for optimization in perceived loading speed, highlighting that relying solely on an optimized framework like Next.js and utilizing SSR techniques is not enough to achieve optimal performance. A more careful and tailored approach to implementation is necessary for optimal results. It should also be noted here that the Vercel's preview deployment might not provide the optimal performance.

Additionally, Semrush flagged that international SEO is not implemented, which is inaccurate. The firewood marketplace app utilizes the xhtml:link alternates in its sitemap to define language variants. However, Semrush does not parse sitemap-based hreflang information, unlike Google. According to Google's documentation, the three acceptable methods for declaring alternate language versions are HTML tags, HTTP headers, and sitemaps, and any one of them is sufficient [125].

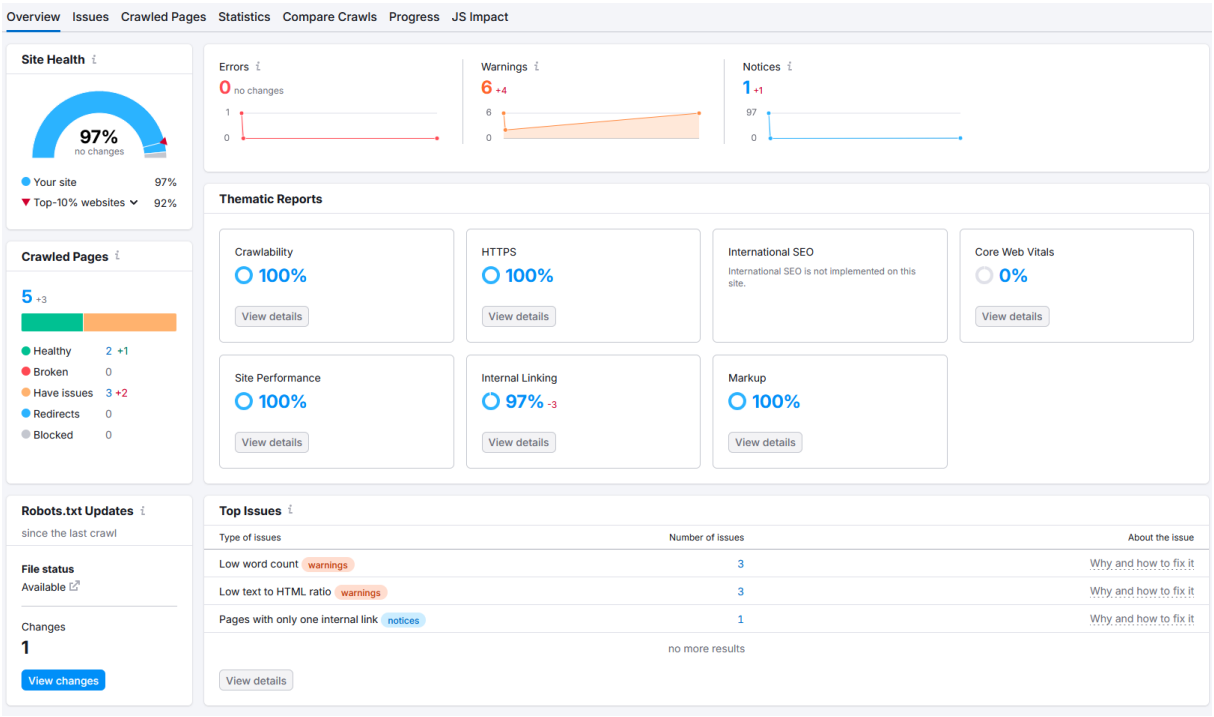

Image 1. Screenshot of the Semrush Site Audit results

7.3.2 Ahrefs Site Audit

Ahrefs Site Audit is a comprehensive SEO crawler tool that scans websites for potential SEO issues. Ahrefs scans internal and external links, analyzes metadata, page structure, duplicate content, hreflang implementation, canonical tags, and mobile optimization, and several other attributes. A Health Score is then assigned based on the ratio of error-free pages to total crawled pages. The tool also flags SEO warnings and notices, ranging from missing meta tags to indexing issues that could impact search engine rankings. Ahrefs was selected for this case study as it was mentioned several times in the literature review in chapter 5. Alongside Semrush, it provides a second perspective to validate the effectiveness of the applied SEO strategies.

The audit was performed on the deployment at dev.polttopuutori.fi, using the default audit configuration in Ahrefs with JavaScript rendering enabled to ensure proper addressing of dynamic content, and the PageSpeed Insights API key added to supplement performance-related analysis. The audit was run three times, and on the last run the setting “Remove URL parameters” was also used to improve the reliability of results by eliminating unnecessary duplicates caused by query strings.

The first audit got a score of 60%, with several key issues (see Image 2). Although there were only a few routes to crawl, the audit kept on running, which was because the links to the authentication pages include a “callbackUrl” query parameter. Ahrefs bots then considered these pages with query parameters different, continuing the crawl. The crawl was then manually stopped after a few minutes.

Ahrefs reported that the hreflang annotations lacked proper return links between localized versions. While this was mostly resolved after correcting the sitemap to include both Finnish and English language versions with full alternate link sets (see Listing 10), one warning persisted for the root page. Despite the correct hreflang configuration, Ahrefs continued to flag this due to its apparent reliance on trailing slash URLs, whereas the sitemap and application use non-trailing slashes consistently. In the application, URLs with trailing slashes are redirected to their counterpart without trailing slash, as it is the default behavior in Next.js [126]. Since Google officially supports both formats as long as consistent redirection is applied [127], this discrepancy was determined to be a limitation in Ahrefs, rather than a real issue.

Listing 10. The sitemap after adding all language versions

```
<urlset xmlns="http://www.sitemaps.org/schemas/sitemap/0.9"
  xmlns:xhtml="http://www.w3.org/1999/xhtml">
  <url>
    <loc>https://dev.polttopuutori.fi</loc>
    <xhtml:link rel="alternate" hreflang="fi"
      href="https://dev.polttopuutori.fi" />
    <xhtml:link rel="alternate" hreflang="en"
      href="https://dev.polttopuutori.fi/en" />
    <xhtml:link rel="alternate" hreflang="x-default"
      href="https://dev.polttopuutori.fi/en" />
    <lastmod>2025-04-28T00:00:00.000Z</lastmod>
    <changefreq>weekly</changefreq>
    <priority>1</priority>
  </url>
  <url>
    <loc>https://dev.polttopuutori.fi/en</loc>
    <xhtml:link rel="alternate" hreflang="fi"
      href="https://dev.polttopuutori.fi" />
    <xhtml:link rel="alternate" hreflang="en"
      href="https://dev.polttopuutori.fi/en" />
    <xhtml:link rel="alternate" hreflang="x-default"
      href="https://dev.polttopuutori.fi/en" />
    <lastmod>2025-04-28T00:00:00.000Z</lastmod>
    <changefreq>weekly</changefreq>
    <priority>1</priority>
  </url>
  <url>
    <loc>https://dev.polttopuutori.fi/auth/sign-in</loc>
    <xhtml:link rel="alternate" hreflang="fi"
      href="https://dev.polttopuutori.fi/auth/sign-in" />
    <xhtml:link rel="alternate" hreflang="en"
      href="https://dev.polttopuutori.fi/en/auth/sign-in" />
```

```
    <xhtml:link rel="alternate" hreflang="x-default"
      href="https://dev.polttopuutori.fi/en/auth/sign-in" />
    <lastmod>2025-04-28T00:00:00.000Z</lastmod>
    <changefreq>monthly</changefreq>
    <priority>0.3</priority>
  </url>
  <url>
    <loc>https://dev.polttopuutori.fi/en/auth/sign-in</loc>
    <xhtml:link rel="alternate" hreflang="fi"
      href="https://dev.polttopuutori.fi/auth/sign-in" />
    <xhtml:link rel="alternate" hreflang="en"
      href="https://dev.polttopuutori.fi/en/auth/sign-in" />
    <xhtml:link rel="alternate" hreflang="x-default"
      href="https://dev.polttopuutori.fi/en/auth/sign-in" />
    <lastmod>2025-04-28T00:00:00.000Z</lastmod>
    <changefreq>monthly</changefreq>
    <priority>0.3</priority>
  </url>
  <url>
    <loc>https://dev.polttopuutori.fi/rekisteroidy</loc>
    <xhtml:link rel="alternate" hreflang="fi"
      href="https://dev.polttopuutori.fi/rekisteroidy" />
    <xhtml:link rel="alternate" hreflang="en"
      href="https://dev.polttopuutori.fi/en/register" />
    <xhtml:link rel="alternate" hreflang="x-default"
      href="https://dev.polttopuutori.fi/en/register" />
    <lastmod>2025-04-28T00:00:00.000Z</lastmod>
    <changefreq>monthly</changefreq>
    <priority>0.3</priority>
  </url>
  <url>
    <loc>https://dev.polttopuutori.fi/en/register</loc>
    <xhtml:link rel="alternate" hreflang="fi"
      href="https://dev.polttopuutori.fi/rekisteroidy" />
    <xhtml:link rel="alternate" hreflang="en"
      href="https://dev.polttopuutori.fi/en/register" />
    <xhtml:link rel="alternate" hreflang="x-default"
      href="https://dev.polttopuutori.fi/en/register" />
    <lastmod>2025-04-28T00:00:00.000Z</lastmod>
    <changefreq>monthly</changefreq>
    <priority>0.3</priority>
  </url>
</urlset>
```

Ahrefs highlighted the issue of duplicate pages without canonical tags on the authentication routes, which is because of the query parameter “callbackUrl” being used on those pages. Since the query parameter changes based on the route that linked to the authentication page, there are essentially several duplicate versions of the page. To fix this issue and prevent duplicate indexing, the canonical versions of those pages were added to the metadata configuration in the generateMetadata functions (see Listing 11).

Listing 11. Including the canonical metatag in the generateMetadata function

```
export async function generateMetadata({
  params,
}: {
  params: Promise<{ locale: Locale }>;
}): Promise<Metadata> {
  const { locale } = await params;
  const t = await getTranslations({ locale, namespace: "metadata" });

  return {
    title: t("page-titles.sign-in"),
    description: t("page-descriptions.sign-in"),
    alternates: {
      canonical: getLocalizedPath("/auth/sign-in", locale),
    },
  };
}
```

Ahrefs also issued warnings about some pages having short or missing meta descriptions and low word counts. The problems with missing descriptions were on pages that have intentionally been set the noindex tag on, and the pages with short meta descriptions were the authentication pages. These could be improved with some better copywriting. The low word count on pages is expected, as the content has not been created yet.

Additionally, Ahrefs pointed out the use of 3xx redirects, which are required for locale switching via next-intl. These redirects do not negatively impact Google rankings and are an expected part of the internationalization setup. The audit also identified a missing og:url tag, which was resolved by explicitly defining it in the generateMetadata function. There was also a warning about a missing viewport tag, but this is a false positive, because Next.js sets the viewport meta tag automatically, making manual configuration unnecessary [128].

After implementing improvements based on the issues identified by Ahrefs and running the audit for the second time, the Health Score increased to 99%. However, this score is not meaningful because of the authentication pages being crawled multiple times with different query parameter values, thus affecting the Health Score value. Therefore, the audit was run for the third time with the “Remove URL parameters” option enabled. This caused a slight drop in the Health Score, making it 97%. The only persistent error-level issue was the false-positive hreflang issue related to trailing slashes, which can be safely ignored in this case. Screenshots from all three Ahrefs Site Audits are shown in Image 2.

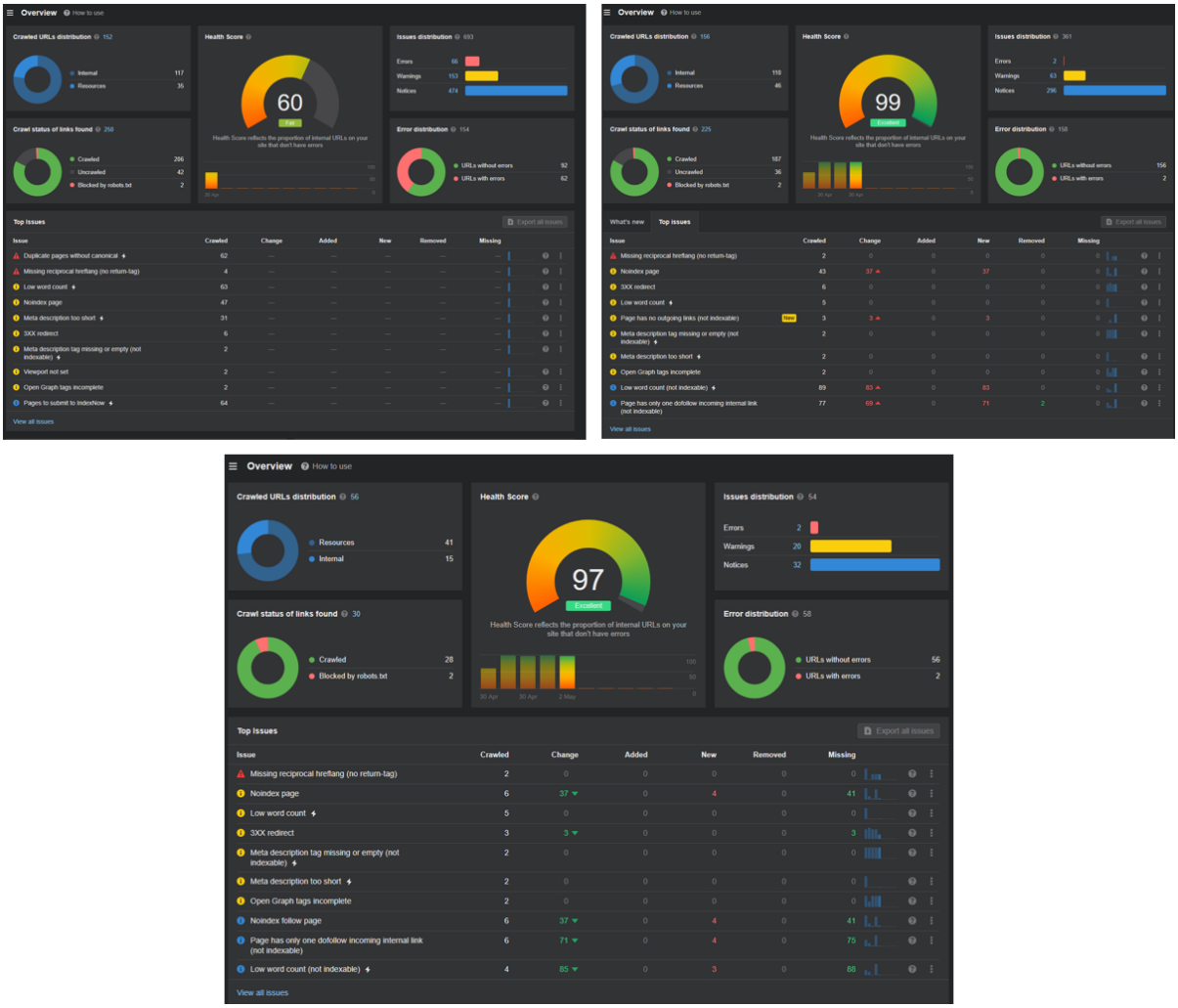

Image 2. Screenshots from Ahrefs Site Audit results

7.3.3 Google Search Console

Google Search Console could be used for the site by verifying domain ownership and submitting a sitemap to allow Google to crawl and index the site. Once connected, it provides useful metrics, such as indexing status, search queries, click-through rates, and mobile usability insights. However, in this case, the tool was not set up for the application, as it is the development version, which should not be indexed. Search Console will be configured once the application is deployed to its production domain.

7.3.4 Google Page Speed Insights

Google Page Speed Insights (PSI) was run on the firewood marketplace app with the default settings for mobile. The results are shown in Image 3. PSI reported perfect score of 100% for SEO, best practices, and accessibility, while the performance score was 87%. The Core Web

Vitals values were the following: FCP 0.9s, TBT 90 ms, Speed Index 0.9 s, LCP 4.1 s, and CLS 0. While most metrics were excellent, the LCP was slower than ideal. PSI identified that 600 ms (15%) of the LCP delay was due to Time to First Byte (TTFB), while the remaining 3,450 ms (85%) was caused by render delay (see Image 4). According to PSI's guidance, most of the LCP time should ideally be spent loading resources rather than being consumed by rendering delays, indicating an opportunity for performance optimization.

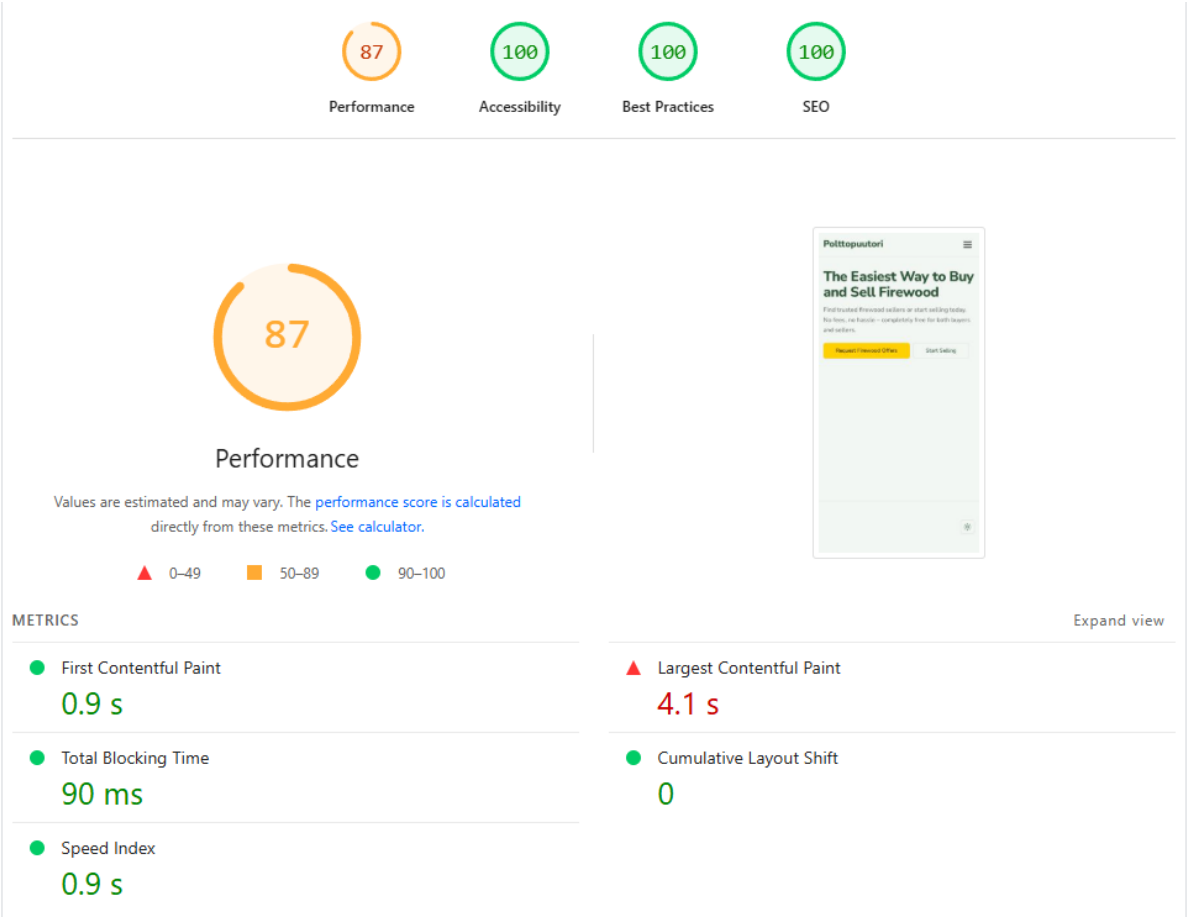

Image 3. Screenshot from Google Page Speed Insights results

Image 4. Google Page Speed Insights LCP details

7.3.5 Google Analytics

Google Analytics can be integrated into the application by adding the tracking script to the root layout. Next.js provides an optimized <GoogleAnalytics> component for this purpose, which can be imported from "@next/third-parties" library. Placing this component in the root layout ensures that the script is loaded for all routes and the pageviews are tracked, if in the Google Analytics Admin panel, the "Enhanced Measurement" property is enabled with "Page changes based on browser history events" checkbox is selected. With this setup in place, it is possible to also send events using the sendGAEvent function from the "@next/third-parties" library. [129] There are several alternatives to Google Analytics, such as Plausible, Matomo, or PostHog, with many of them more privacy focused.

7.3.6 Analysis of Results

The SEO evaluation shows that, despite being in early development, the application demonstrates strong technical and on-page SEO implementation. Both Semrush and Ahrefs audits reported high scores (97%), with most issues, such as low word count or hreflang warnings, resulting from tool limitations or the absence of real content. These results suggest a clear correlation between the techniques identified in the chapter 5 literature review and strong site audit scores.

While the lack of content expectedly led to some warnings in the audits, the poor LCP score was an unexpected outcome. This emphasizes the importance of implementation quality, even when using optimized frameworks, such as Next.js.

Since the application is still in the development phase, it is not yet appropriate to create a GMB profile or add NAP details to the site. However, these steps will be important for local SEO in the production phase. Similarly, off-page and online content SEO strategies should be prioritized as the application matures.

To support answering RQ4, "How can SEO performance of a web application be measured using Google's tools, and how can these measurements be used to improve SEO in a deployed application?", the usage of Google Search Console, PageSpeed Insights, and Analytics was reviewed. The section demonstrated on a high level how each tool can be configured and used in practice to start tracking the performance for making iterative SEO improvements once the application is deployed to production.

7.4 Conducting pSEO

This subchapter presents how pSEO can be practically implemented in the context of the firewood marketplace app, with a particular focus on its technical aspects. The steps followed are based on the framework presented in chapter 6.4.1, which was developed using insights from the qualitative content analysis. Since establishing a solid SEO foundation is crucial before scaling, this subchapter serves as an example case and a plan for future implementation rather than directly executing pSEO.

7.4.1 Developing a pSEO Strategy

The first step is conducting in-depth niche, competitor, and audience research to identify opportunities and set goals. Niche research was carried out to evaluate the overall business potential of the firewood marketplace app. However, the detailed findings are excluded from this thesis to protect the business concept.

Competitor research began with exploratory Google searches using relevant Finnish keywords for firewood, such as "polttopuu" (firewood) and "klapi" (log or split wood). These searches revealed key competitors in the market, including mottinetti.fi, halkoliiteri.com, klapila.fi, tori.fi, polttopuuta.net, and puutukkuri.fi. Further insights were gathered using Semrush's Domain Overview and Organic Research tools. Analysis showed that most of the competitors

lacked localized landing pages for long-tail queries, such as “polttopuut Turku kotiinkuljetus” (firewood delivery in Turku). They also seemed to rely on generic or non-optimized product pages, with no structured approach to capturing location-specific search intent, highlighting a clear opportunity for scalable pSEO.

For example, Semrush data revealed that Mottinetti ranks organically for keywords such as “polttopuun hinta” (firewood price), “polttopuuta” (partitive form of firewood), and “myydään polttopuuta” (firewood for sale). Based on Semrush, its top competitors include halkoliiteri.com, klapitkotiin.fi, and puutukkuri.fi. Similarly, for Halkoliiteri, Semrush identified high-ranking keywords like “polttopuuta”, “heittomotti” (a loose cubic meter of firewood), and “polttopuiden lämpöarvot” (heat values for firewood). Notably, over 88% of the top-ranking keywords for both competitors had informational search intent, with only around 10% having clear commercial or transactional intent.

Additionally, there are several Facebook groups where users post requests for firewood. This is useful for audience research. Based on a few requests from such groups, these typically include quantity of firewood in cubic meters, firewood length, delivery details, and possibly intended use for the firewood. Sellers then respond either publicly by commenting to the post or via private messages. Geographic specificity and urgency are common. Clearly, key decision factors include wood type, dryness, price, and delivery speed.

Based on the research, the pSEO strategy could focus on targeting different locations. The content should align with high-conversion queries. Since the application serves two types of users, buyers and sellers, it would be possible to target both groups separately. However, focusing on buyers directly also increases visibility among potential sellers. Therefore, it may be sufficient to concentrate on targeting buyers, provided that the pages are also designed to convert firewood sellers into users of the platform. The primary objective of the pages should be to guide users toward requesting firewood offers.

7.4.2 Conducting Keyword Research

The next step in developing the pSEO strategy involves conducting detailed keyword research to identify scalable opportunities. This process focuses on discovering high-intent, long-tail keyword variations that can support the generation of location-targeted landing pages aimed at buyers.

Semrush's Keyword Magic Tool was used to explore combinations of relevant head terms, geographic modifiers, and intent-driven keywords. The primary head terms include common Finnish words for firewood and related products, such as "polttopuu", "klapi", "halko", and "koivuklapi" (birch log). These were input in the tool's search field with Finland set as the database and EUR as the currency. Among these, "polttopuuta" had the highest search volume (6,600 average monthly searches), followed by "koivuklapi" (1,000), klapi (880), and halko (720). Semrush marked all of these keywords as having commercial intent and easy keyword difficulty.

The head terms were then combined with city-specific location modifiers, such as Turku, Tampere, and Helsinki, to identify localized demand. For instance, "polttopuut Tampere" had a commercial intent with 590 monthly searches and a very easy keyword difficulty of 6%. Intent modifiers signaling stronger transactional or commercial intent were also tested. Examples of such modifiers include "edullista" (cheap), "toimitus" (delivery), and "hinta" (price). For example, "edullista polttopuuta" (cheap firewood) had a commercial intent with 1,300 monthly searches and a very easy keyword difficulty of 11%, and "polttopuun hinta" (firewood price) had a commercial intent with 2,400 monthly searches and a very easy keyword difficulty of 7%.

The combination of these elements produces long-tail keywords, such as "edullista polttopuuta Turku" (cheap firewood Turku) or "koivuklapi toimitus Helsinki" (birch log delivery Helsinki). These terms are ideal for pSEO because they are both specific and scalable. One template can be used to generate hundreds of landing pages with dynamically generated content targeting different combinations of product type, location, and purchase intent.

7.4.3 Designing and Building Programmatic Pages

Once the keywords have been selected, the next step is to generate SEO-friendly landing pages. Since the firewood marketplace app is built with Next.js and next-intl, the programmatic pages must be generated in a specific manner.

The routes and their localized versions are defined in a next-intl configuration file, routing.ts. To enable generation of pages in arbitrary URLs optimized for SEO, a dynamic URL route, for example "/[slug]", must be added to the routing pathnames configuration (see Listing 12). Next, the data of the programmatic pages should be stored in a database. Since the project

already uses Neon Serverless Postgres, it is a suitable choice. The database should have a table to store the programmatic page data, including the URL slug (e.g., “edullista-polttopuuta-turku”), locale, metadata information, and content, such as the text and image URLs. If it is desired to provide different language versions of the pages, information about the different locale versions of the page could also be included in the page records in the database. This way, switching languages could simply link to the appropriate language version of the page.

Listing 12. Adding the [slug] route in the next-intl routing configuration

```
export const routing = defineRouting({
  locales: [”fi”, ”en”],
  localePrefix: ”as-needed”,
  defaultLocale: ”fi”,
  pathnames: {
    ”/”: ”/”,
    ”/[slug]”: ”/[slug]”,
    …
```

The pages can be generated in Next.js by creating the dynamic route in the app router as “/[locale]/[slug]/page.tsx“. This page file contains the template for the generated pages. The page can retrieve the slug from the URL parameters and then fetch the content of the page utilizing the unique slug as the identifier in the database. The data can then be inserted in specified locations to populate the page with unique content. Additionally, the data can be used to fetch other relevant information, such as testimonials or location-specific details. One particularly important aspect of the generated pages is internal linking. Each programmatic page should be linked to other pages on the website, as well as to other relevant generated pages. This linking information should also be stored in the database. The generateStaticParams function can be utilized to statically generate pages for all of the slugs at build time. A simplified example of generating pSEO pages is shown in Listing 13.

Listing 13. Generating pages using generateStaticParams, generateMetadata, and a page template

```
export async function generateStaticParams() {
  const slugs = await getAllSlugs();
  return slugs;
}

…
```

```
export async function generateMetadata({
  params,
}: {
  params: Promise<{ slug: string; locale: Locale }>;
}): Promise<Metadata> {
  const { slug } = await params;
  const pageData = await getPageBySlug(slug);
  return {
    title: pageData.metadata.title,
    description: pageData.metadata.description,
  };
}

export default async function Page({
  params,
}: {
  params: Promise<{ slug: string; locale: Locale }>;
}) {
  const { slug } = await params;
  const data = await getPageBySlug(slug);

  if (!data) notFound();

  return (
    <div>
      <h1 className="h1">{data.hero.h1}</h1>
      <p className="p">{data.hero.sub}</p>
    </div>
  );
}
```

7.4.4 Creating High-Quality Content

The next step involves creating high-quality content for the generated pages. This content should match user search intent and provide genuine value to visitors. AI tools can be utilized to assist in producing the content, with manual refinement to ensure accuracy, relevance, and a natural tone. However, the specifics of content creation fall outside the scope of this case study.

7.4.5 Creating and Managing Sitemaps

To support efficient indexing of the programmatically generated landing pages, the sitemap should be created and managed systematically. In a Next.js application, the sitemap can be generated programmatically by fetching all relevant page records from the database and mapping them to form the appropriate sitemap structure. The programmatic generation of a sitemap is demonstrated in chapter 7.2.9. Generating the sitemap based on the database records ensures that all programmatic pages are included in the sitemap. To maintain the

sitemap, the app should be automatically rebuilt when pages are updated or new ones are created, so that the sitemap is regenerated accordingly.

The generated sitemap should be submitted to Google Search Console to inform search engines about the available pages. If the number of generated pages grows significantly, it may be beneficial to split the sitemap into multiple files.

7.4.6 Acquiring Backlinks for Authority

Acquiring backlinks is an important strategy to increase domain authority and improve rankings. However, this step is out of the scope of this case study.

7.4.7 Maintaining and Improving Pages

To ensure long-term effectiveness, the performance of the programmatically generated pages should be monitored using data from analytics tools, such as Google Analytics and Google Search Console. Underperforming pages can then be refined based on user behavior data and search metrics. Maintenance should also include updating the content regularly, conducting technical SEO audits, and adjusting internal linking and metadata to sustain search visibility.

This case study has illustrated how SEO, including both traditional and programmatic methods, can be practically implemented and evaluated in a real-world web application. The chapter detailed how the key technical and on-page SEO techniques can be implemented in a localized Next.js application, and how potential issues can be addressed early by utilizing site audit tools. The final section demonstrated how pSEO can be conducted in practice to generate large numbers of pages targeting different carefully chosen long-tail keywords.

8 Discussion

This chapter reflects on the main findings of the thesis by addressing each of the research questions. Once all four questions have been discussed, the chapter looks at how these findings relate to earlier research, points out the main limitations of the work, and suggests ideas for future studies.

RQ1: “How to improve the visibility of a web application in Google Search results?”

Answer: The most effective way to improve a web application’s visibility in Google Search is by implementing a comprehensive SEO strategy and optimizing all key areas, including on-page SEO, off-page SEO, technical SEO, user experience, online content, and local SEO. SEO is a long-term strategy that requires time and constant effort to deliver results.

The literature review in chapter 5 synthesized findings from 31 studies, including practical recommendations that were organized into the categories presented in Tables 8-15. On-page SEO techniques include keyword research and integration, optimizing metadata, images, and page URLs, selecting an appropriate domain name, and correctly using heading tags and semantic HTML. Off-page SEO includes building high-quality backlinks, encouraging reviews and testimonials, and enhancing social media engagement. Technical SEO focuses on site architecture, mobile optimization, the use of HTTPS, internal linking, setting up redirects to avoid broken links, and ensuring crawlability through proper robots.txt files and XML sitemaps. Implementing schema markup and managing duplicate content through canonical tags are also critical elements. User experience plays a key role, with emphasis on fast loading speeds, responsive design, and intuitive navigation. High-quality online content is vital, with a focus on valuable, consistent, and SEO-friendly content in various formats. Content should be semantically rich and easy to read, ensuring it meets both user intent and search engine algorithms. Local SEO ensures visibility in regional searches by optimizing for local keywords, maintaining consistent NAP information, encouraging reviews, and targeting local audiences with localized content and TLDs.

In the case study in chapter 7, the best practices from literature were applied to a prototype firewood marketplace app, resulting in impressive SEO scores of 97% from site audits with both Semrush and Ahrefs. This demonstrates that the recommended techniques contribute to high SEO audit scores. However, a surprisingly poor LCP score highlighted that using optimized frameworks like Next.js is not enough to ensure good performance. Based on the

literature review and the case study, a web application's visibility can be improved in Google Search results by implementing a comprehensive SEO strategy and adapting it over time.

RQ2: "How to utilize Programmatic SEO to improve visibility of a web application in Google Search results?"

Answer: pSEO can be utilized to improve the visibility of a web application in Google Search by following a seven-step framework:

1. Develop a pSEO strategy based on niche, competitor, and audience research
2. Conduct keyword research to identify scalable long-tail keyword variations
3. Design and build programmatic pages utilizing page templates and data
4. Create high-quality content that aligns with search intent
5. Create and manage sitemaps covering all programmatic pages
6. Acquire backlinks to build domain authority
7. Maintain and improve pages based on data

The literature review in chapter 5 revealed that academic research on pSEO is almost non-existent. Consequently, a qualitative analysis of 42 industry blog posts and expert articles was conducted in chapter 6 to define pSEO and identify the key techniques. Based on this analysis, pSEO was defined as "a data-driven approach to search engine optimization that leverages automation, templates, and structured data to create and optimize large volumes of web pages at scale, primarily targeting long-tail keywords to improve search rankings".

A wide range of pSEO techniques was collected from the articles, which were then clustered into seven superclasses of techniques: developing a pSEO strategy, conducting keyword research for pSEO, designing and building programmatic pages, creating the content for the pages, managing sitemaps, maintaining and improving the pages, and acquiring backlinks. These superclasses were then utilized to form the steps of the framework for conducting pSEO.

The case study in chapter 7 demonstrated how this pSEO framework can be implemented in a modern Next.js application in practice. The impact of pSEO was not empirically evaluated in search results. Therefore, the study does not directly show that utilizing pSEO improves

visibility in Google Search. However, by generating a large number of SEO-optimized pages that target low-competition keywords, it can be inferred that such pages may improve visibility in Google Search for those targeted keywords. Additionally, the analyzed blog posts and expert articles included several success case studies clearly demonstrating the positive effect of pSEO on visibility in search results.

RQ3: “How can SEO be implemented in a multi-locale application to improve visibility in Google Search results?”

Answer: SEO for a multi-locale web application can be implemented by applying proven SEO and local SEO techniques tailored for each target region.

The literature review in chapter 5 provided several local SEO recommendations, including local keyword optimization, maintaining a GMB profile, local citations, and ensuring NAP data consistency. In addition, creating localized content, targeting niche local audiences, and acquiring customer reviews are key components of local SEO. Although the literature review did not directly address multi-locale SEO, the strategies for optimizing SEO in one locale, such as targeting local keywords and local content creation, can be scaled and adapted for multiple regions. For example, if a business has multiple locations in different regions, it should create separate GMB profiles for each location, ensuring that each profile contains accurate and consistent NAP data.

When expanding SEO efforts across multiple locales, the use of hreflang tags becomes essential. Hreflang tags help Google serve the correct version of a page to users in different regions and languages. The importance of properly configuring hreflang tags was highlighted in the case study in chapter 7, where Ahrefs Site Audit highlighted problems in the hreflang configuration. Additionally, employing region-specific subdirectories (e.g., “/en”, “/fi”) or country-level domains ensures that search engines can identify the relevant content for each market. The case study demonstrated how basic SEO techniques can be applied in a multi-locale Next.js web application, using the next-intl library for internationalization.

RQ4: “How can SEO performance of a web application be measured using Google’s tools, and how can these measurements be used to improve SEO in a deployed application?”

Answer: The SEO performance of a web application can be measured and improved using Google Search Console, Google Analytics, PageSpeed Insights, and Rich Results Test. These

tools enable continuous monitoring of both technical and content-related KPIs, creating a feedback loop where data insights guide ongoing optimization after deployment.

The literature review in chapter 5 outlined best practices for measuring and maintaining SEO, emphasizing the importance of tracking both traffic-related KPIs and technical KPIs. Audit tools such as Semrush and Ahrefs, as discussed in the case study in chapter 7, provide comprehensive data about the state of SEO of the website. In addition, A/B testing and SEO forecasting tools can be utilized to make more informed decisions. Maintaining SEO is a continuous process, and regular evaluations using Google's and third-party tools are necessary to sustain and improve visibility in search engines.

Google Search Console provides critical insights into indexing status, search queries, CTR, keyword rankings, and crawl issues. It also enables site administrators to address technical problems such as broken links and indexing errors, and to submit updated content for re-crawling. Google Analytics tracks user behavior, acquisition channels, conversion rates, bounce rate, and session duration, which are key indicators of user engagement and content relevance. PageSpeed Insights provides actionable insights into Core Web Vitals, including LCP, FID, and CLS, which are key metrics for assessing load speed, interactivity, and visual stability. Rich Results Test can be used to validate structured data on a webpage, ensuring that it is correctly implemented to enhance the display of rich results in SERPs.

The case study showed how these tools can be used in practice to monitor and improve a deployed Next.js application. For example, PageSpeed Insights identified a low LCP score, prompting optimizations to page loading speed. While Google Analytics and Google Search Console were not applied in the project's development stage, their setup and implementation steps were discussed. Rich Results Test was used to validate the schema markup that was added to the site.

The findings of this thesis support earlier studies showing that all of the SEO areas are important, and lacking in any of them can harm overall performance. The research in this thesis builds on that knowledge by introducing pSEO as a complementary strategy to traditional SEO approaches. This contribution is particularly valuable, as no academic work has yet explored pSEO in-depth, making it a novel addition to the field.

However, there are some limitations to consider. This study did not incorporate A/B tests or SERP experiments to measure the impact of the changes on visibility in Google Search,

instead, site audit tools were utilized. Future research could explore how site audit results from tools such as Semrush or Ahrefs correlate with real search visibility. Additionally, evaluating the impact of individual SEO techniques on SERP rankings would be valuable. Such studies could help prioritize SEO strategies and rank them according to their importance. Additionally, the impact of pSEO on search visibility and organic traffic was not directly assessed in this study. Further research could investigate how pSEO campaigns influence these metrics.

As the search landscape evolves, the rise of large language models (LLMs) and chatbots could fundamentally change how people search for information. This shift may require SEO strategies to evolve as well, expanding beyond traditional optimization for users and search engines to include these generative engines. Early research suggests that Generative Engine Optimization (GEO) methods can improve source visibility in generative engine responses by up to 40% [130].

9 Conclusion

This thesis explored how search engine optimization (SEO), particularly programmatic SEO (pSEO), can be effectively implemented in localized web applications to improve visibility in Google Search. The research was motivated by the development of a real-world firewood marketplace app, which served as the platform for applying and evaluating SEO techniques.

The thesis began by establishing a solid theoretical foundation, outlining the core technologies behind web applications, the functioning of search engines, and foundational SEO concepts. A literature review identified effective SEO practices, categorized across on-page, off-page, technical, optimized user experience, online content, and organic local SEO. While the literature review covered various aspects of SEO, it did not specifically address pSEO, highlighting a gap in academic research on the topic.

Given the limited academic research on pSEO, a qualitative content analysis was conducted on expert-authored blogs and articles to define pSEO and identify key techniques for implementing it. pSEO was defined as a data-driven approach to search engine optimization that leverages automation, templates, and structured data to create and optimize large volumes of web pages at scale, primarily targeting long-tail keywords to improve search rankings. Key pSEO techniques were grouped into a step-by-step framework for conducting pSEO: developing a pSEO strategy, conducting keyword research, designing and building programmatic pages, creating high-quality content, creating and managing sitemaps, acquiring backlinks, and maintaining and improving pages.

The final phase of the research applied these SEO and pSEO techniques to the case study application. This included implementing key on-page and technical SEO elements, such as optimizing metadata, generating the sitemap, and adding schema markup. SEO audit tools were used to evaluate SEO performance after applying the techniques, indicating that the applied techniques correlate with high SEO audit scores. Additionally, the case study demonstrated how pSEO can be conducted in practice.

In conclusion, this thesis answered the research questions by reviewing established SEO practices, analyzing content on pSEO, and applying these findings to a real-world case. It provides a clear, actionable framework for conducting pSEO, and demonstrates how both SEO and pSEO techniques can be effectively applied to multi-locale web applications, contributing to the field of SEO research and practice.

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