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Abstract

Over recent years there has been an emergence of food scandals attributed to contaminations with chemical or microbiological hazards. In 2008, in China, ten dairy companies were found to add melamine, a nitrogen-based compound, into infant formula in an effort to artificially boost the protein content (1). Melamine is especially used in the production of plastic; thus, approximately 300,000 were affected, and six deaths were reported (1). These high numbers are attributed to the lack of tools the local authorities had to trace these contaminated batches, thus endangering the consumers' lives for some time after the incident was discovered. There seems to be a general consensus that granting these tools would allow the guard against similar food scandals.

Therefore, we can safely say that determining a product's provenance at any point in the manufacturing lifecycle is one of the most critical issues that need to be addressed. Currently, there exists a limited number of solutions in both centralized in decentralized supply chains, in the form of applications and decentralized applications (dApps). In this paper, we focus more on the latter one. Whilst there are a few pilot programs that address the issue of provenance tracking, they fail to be accessible to the population suffering from disabilities or old-age. In addition, little to no-research has been done on features that improve the accessibility of their solution.

To fill in this gap, we propose an application, accessible regardless of age, language spoken, device owned or disabilities of the user, that helps trace supermarket aliments from farm to table. We have used two methodologies, *Design Thinking*, and *Atomic Design*. Furthermore, we conducted a survey *(N = 53)* with the intent of gathering feedback on the quality and correctness of the methodology adopted.

The first research question we answer is: "To what extent does a high level of accessibility provided by the application and a high level of user proficiency lead to increased satisfaction levels?". Having succesfully answered the first one leads to the second question: "What is the most suited framework to develop an application for a broad audience?".

Our results show that neither self-assessed proficiency nor perceived levels of accessibility were factors to the overall satisfaction. Instead, we have found that the last level of education completed and interest shown towards knowing more about the product's provenance to impact satisfaction positively. Lastly, we found Angular to be the most suited framework for developing an application able to trace the product's provenance. The colour-blind respondents *(N=6)* rated the application's features highly to overcome their imparity.

Keywords— provenance, blockchain, decentralized application, traceability, visual impairment, colour blind, daltonization, accesssibility,

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1 Introduction and Motivation

Problem Definition

One of the most critical issues that supply chains face in the current day is determining the provenance of an object or entity at any point in the logistical process. Provenance can have a broad spectrum of purposes, such as tracing back faults throughout the production process or identifying contaminated batches that require removal from the custody of downstream retailers, which otherwise might endanger the lives of consumers. The black market is on the rise, and it is estimated that between 2005 and 2010, an operation kicked off by the FBI and the United States Customs led to the seizure of $143 million worth of counterfeit network hardware (3). The Organisation for Economic Co-operation and Development (OECD), an organization consisting of 38 member states, places the value of imported counterfeit trade at $509 billion in 2016 (4).

While humanity does not have a profound issue against the existence of knock-off apparel and pirated goods, it is important to know that sensitive sectors may be affected by their existence. In the second half of 2008, in China, it was discovered that the dairy industry was adding melamine into milk and infant formula in an effort to boost the protein content artificially. Around 300,000 infants were affected and 6 deaths reported according to (1). Fast forward to the present date, the local industry has never recovered, and 80% of the formula sold within China is imported (5). The medicine supply chain has been seeing an increase of over 120% in the period between 2005 and 2010 in terms of counterfeit incidents, according to Pharmaceutical Security Institute (PSI). The provenance issue goes as far as the use of chemical fertilizers and manure, which negatively affect the quality of the water used for agriculture, as well as that of the aquatic ecosystems, and thus, the intake of marine species. The intoxication of marine species has a direct effect on consumer health.

Motivation

As a consequence, traceability is divided into mandatory and voluntary traceability, with the first encompassing only as much as the source, shelf life, and batch number. This information is, however, hardly sufficient to reassure consumers or prevent incidents as previously described. Therefore, we see a shift towards increased voluntary traceability, encompassing more detailed information made available by producers or distributors concerning the production process and the modifications inflicted on the goods (6). There seems to be a general consensus that a significant part of these issues could disappear if the authorities had the right tools to combat this. Additionally, granting access to these tools to the average consumer would allow them to guard against similar food scandals and health endangerment. Part of the reason traceability is not implemented in supply chains comes down to the laborious process of centralizing information from multiple diverse supply chain members and difficultness of implementing such technology. Moreover, there are concerns regarding sustainability regarding centralization of supply chain information (7).

There are currently solutions to address the provenance of products within various centralized or decentralized supply chains, as we will discuss shortly. However, most of these solutions fail to address an important aspect — that is accessibility. These solutions should be available for everyone regardless of age, language spoken, device owned, or disabilities. Nevertheless, the companies spending millions on implementation costs focus on an overwhelming complex design regarding layout, navigation, and interaction behaviour and thus makes it hard for the consumer to use the product. According to (8), a study done in 2022 on the top 1,000,000 websites in the world, an estimated 50.8 errors were detected per page. Government websites have 41.9% fewer errors than the average. On the other side of the spectrum are real estates and retail websites that have 34% and 43.4% more errors than the average. Besides this being an ethical issue in itself, it should also be a source of worry for these companies. In an effort to increase the importance of digital accessibility, governments world-wide have started to introduce laws requiring companies to make their websites accessible to everyone. In 2014, the European Union introduced a law requiring all the websites and mobile applications managed by the public sector to be accessible by 2018 and 2021, respectively (9). Failure to comply can result in lawsuits up to $350,000 as estimated by (10).

Aims & Objectives

Taking into consideration the above, we propose an application accessible to any user regardless of age, device owned, language spoken, disabilities or proficiency in using technology, that helps trace supermarket aliments from farm to table through each step in the logistical process. After completing the implementation of the application, we will design and distribute a survey. The primary scope of the survey is to gather feedback on the quality and correctness of the methodology adopted while implementing the application. The secondary motive is to conduct an investigation towards designing dApps for individuals with visual impairment.

As a result, the following research questions have emerged:

1. **What framework would be most suited for the development of an accessible application to manage provenance for supermarket products?**
2. **To what extent does a high level of accessibility provided by the application and a high level of user proficiency leads to increased levels of satisfaction?**

Consequently, with the successful implementation of such applications and answering of our research questions, we expect to make contributions towards:

1. A real-time dashboard of a provenance tracker, which may be used by the general public interested in knowing more about what they consume.
2. A set of guidelines that help companies interested in blockchain-based solutions to design accessible dApps with human-centeredness at its core.

Structure of the thesis

The rest of this paper is organized as follows. In section 2, we present the theoretical background and literature review, containing the most recent developments within the field, related work, and comparison between related work and our proposed solution. In section 3, we present the methodology adopted and planning to be executed. Section 4 contains details concerning the design and implementation of our proposed solution. In section 5, we discuss the evaluation of our solution and answer our research questions. In section 6, we conduct a discussion and lastly, in section 7, we present our findings in conclusion and include potential future work on the project.

2 Background and Literature Review

2.1 Background

2.1.1 Blockchain

The term of blockchain is used to represent decentralized systems that store and transfer data, arranged securely in a series of blocks with the help of cryptography (11). Each block contains an irreversible hash containing information related to the previous block, a timestamp representing the date and time at which that specific block was created, and transaction data representing the state of the network. The only block not containing a information related to the previous one, is called Genesis, and represents the first block to be mined in the network. Other than this, as a consequence of each block containing information to the previous one, it can be compared to as a chain continuously growing. Once a record is added to the blockchain, it is immutable, without altering all subsequent blocks (11). Figure 1 shows the typical structure of a blockchain network.

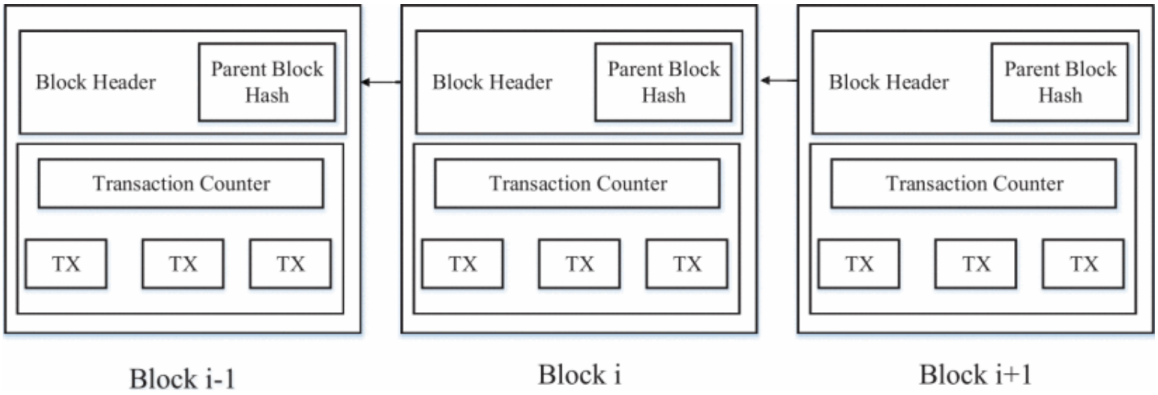


Figure 1: A typical structure of a blockchain network. Image from (12)

Since it allows transactions to be completed without intermederies, it has found great uses cases in financial services (13), electronic voting (14), and public services (15). Another important advantage of the blockchain stands in distributed nature, meaning that its state is synchronized with all the other nodes within the network; thus, avoiding a single point of failure (12). The process which determines the blocks to be added to the network and its state, is called *consensus* (16). There exists three types of the blockchain: public, private, and consortium (16).

The benefits that spur from the use of blockchain are, among others, transparency, visibility, transaction efficiency, and security (7).

2.1.1.1 Smart contracts and Decentralized Applications

Ever since the first implementation of a distributed ledger technology (DLT) in 2008 (17), the concept of blockchains and cryptocurrencies have been heavily intertwined with a vast majority of people being misled into thinking that they are one or the same (known as Blockchain 1.0). Only in the last couple of years the new emergence of systems involving blockchain technology has gained massive momentum, with a wide variety of applications ranging from electronic voting to supply chains according to (14) & (18). Credit can be given to the implementation of smart contracts (built on Blockchain 2.0 systems), which facilitate the execution of code pre-agreed upon by various parties (19). One of the most popular frameworks for building smart contracts the Ethereum network is is Solidity. On the Hyperledge Fabric, smart contracts are called *chaincode* and can be written in Golang, Node.js, or Java.

As soon as a smart contract is launched onto a blockchain, its internal code cannot be altered and thus achieves some grade of security. Another important landmark in blockchain (3.0) is the introduction

of decentralized applications (dApp), that, through the use of smart contracts, can create a new suite of technologies ranging from finance to governance.

When it comes to building dApps, on the Hyperledger Fabric Network there exists SDKs for Python, Golang, Java, and Node.js (20).

2.1.2 JavaScript

In 1995 a company named Netscape released JavaScript in an attempt to change the way web pages were being built. It debuted in the same company's web browser, Netscape Navigator. In those early days, new content could not be added after the page was loaded, hence why it was referred to as "the static web". Later in the year, Microsoft was able to reverse-engineer Javascript to create its own, called JScript, and released it in Internet Explorer. Netscape and Microsoft were seen as rivals in an attempt to establish their position in the web browser market, and there was a divergence in how web pages were rendered on each browser. Despite earlier collaborations between the two companies to standardize JavaScript with the first release of ECMAScript in 1997, Microsoft eventually stopped implementing proposals within JScript when Internet Explorer reached an astonishing 95% market share and therefore achieved a monopoly (21). Because of this, the web development field became stagnant, with many standards not being released or adopted.

In 2004 the Firefox browser was released by Mozilla, and the standardization of Javascript started once again to become more active. In 2008, Google launched Chrome v8, a new Javascript interpreter written in C++ that is 56 times faster than Internet Explorer's (22). The V8 engine features inline-caching and a new approach called Just-in-Time Compilation (JIT), a significant upgrade compared to the previous standard of ahead-of-time compilation (AoT), which improves speed and effectiveness drastically. With the help of Mozilla, many standards came after with the latest being ECMAScript 6 (ECS6).

Although Javascript had played a minor role in manipulating CSS and HTML client-side, the introduction of v8 opened a new horizon of advancements in the web development field. One is Node.js, a new cross-platform run-time environment for building scalable and maintainable server-side applications. As of 2022, the usage of Javascript in client-side applications has skyrocketed to 98% (23)

2.1.2.1 TypeScript

Microsoft went on to release TypeScript in 2012 as a syntactic superset of JavaScript. It aimed to solve the abundance of bugs that Javascript web developers were experiencing by adding optional static typing. Doing so facilitates IDE support and enables developers to catch mistakes early in the process.

A benefit of being a JavaScript superset means that existing Javascript code-bases are also valid in Typescript. Typescript code is compiled into Javascript at run-time, and therefore, it can be run anywhere Javascript can.

2.1.3 JavaScript frameworks and libraries

Building on the success of Javascript is not just Node.js. With it came a new emergence of frameworks and libraries that aid developers in creating web applications. These frameworks provide standards and sufficient low-level functionality such that web developers can focus solely on the essential aspects of their projects.

2.1.3.1 React

React is one of the most popular libraries for building user interfaces. It was developed by Meta, formerly Facebook, in the year of 2013 as an open-source Javascript ES6-based library. It can be used to create single-page, server-rendered mobile applications. Its structure is entirely based on components, thus making code reusable and achieving less technical complexity. These components are rendered based on some properties of a particular Document Object Model (DOM) element. React uses a virtual copy of the DOM which computes the differences compared to the real DOM and thus achieves a much higher efficiency (24). Changes to the DOM are done by hooks, which are functions that allow the execution of code at specific points during the lifecycle of a component based on its state. React does not use the typical Model-View-Controller architecture and instead creates its own, called Flux. While this brings some advantages in terms of efficiency, it supports only a unidirectional data flow, which requires the developer to write more code.

2.1.3.2 Vue

Vue is an open-source Javascript ES6-based library initially released in 2014 by Evan You used to build user interfaces and single-page applications (25). Although with its first release, it contained limited functionality and thus made it hard to use Vue for large architecture commercial applications, the open-source community quickly stepped in. It implemented third party libraries for state management, and routing (26). Vue uses a Model-View-Viewmodel (MVVM) design pattern that facilitates the way data is shared between the components triggered by DOM listeners and thus can achieve both one-way and two-way data binding (26). Vue is also structured based on components that extend traditional HTML elements to encapsulate custom behaviour, thus achieving reusable code (26).

2.1.3.3 Angular

Angular is the oldest web framework developed by Google, and its first version (AngularJS) was released in 2010. This initial version was written in Javascript and adhered to the MVC architecture. The intent was to aid the creation of SPAs only on the desktop platform, which might be linked to the fact that mobile usage was still relatively low at that time. The state of Angular has changed drastically throughout time, but the most notable one is with the release of its second version, which supported Typescript and became more suited toward mobile, and cross-platform development (27). With the introduction of TypeScript, Angular gradually allowed developers to write and maintain more architectural-heavy applications. Components are structured neatly and composed of separate files responsible for HTML, CSS, TypeScript, and testing. These components can then be declared into modules. The logic part of the application is typically withheld by services running in the background side of the application. While Angular comes with extensive tooling able to tailor the experience of the developer, there seems to be a portion of developers that argue as this has a negative connotation due to the increased build size and thus limiting the performance.

2.1.4 Visual Impairment

Visual impairment is caused when an eye condition affects the visual system by disturbing one or more of its functions. These functions can have a large suite of applications such as:

1. Visual acuity allows us to clearly distinguish the details on objects clearly, no matter the distance to the object.
2. Color vision, which allows the differentiation of objects that have a similar shape and size
3. Depth perception helps us gain insight into the distances of approaching objects.

In a report done in 2019 by the World Health Organization (WHO), visual impairment can be separated into five categories ranging in severity, and it is based on the visual acuity in the better eye. This categorization can be observed in table 1.

Table 1: Classification of visual impairment's severity based on visual acuity based on (2)

Category	**Visual acuity**	
	Worse than:	**Equal to or better than:**
Adequate vision	6/6	6/12
Mild vision impairment	6/12	6/18
Moderate vision impairment	6/18	6/60
Severe vision impairment	6/60	3/60
Blindness	3/60	

Visual acuity is assessed with the help of a vision chart at a fixed distance of 6 meters (28). The indicators used to assess the quality of the vision can be represented in fractions, as seen in table 1. The numerator denotes the distance from which the chart is situated against the eye. The denominator expresses the distances at which a "healthy" eye can read off the vision chart. For example, a person who

has severe vision impairment with a visual acuity of 6/60 means that the chart is viewed at a distance of 6 meters and that a person with adequate vision can read the same letter at a distance of 60 meters.

2.1.5 Color Vision Deficiency

Color vision deficiency (CVD) is one of the most relevant conditions that affect the perception of color in the human eye. One in 12 males (8%) and one in 200 females (0.5%) seem to be affected by CVD (29). In cultures where consanguineous marriages happen in higher rates, the frequency of males suffering from CVD is also high, namely 15% (30). Affected individuals are not only hindered from their daily activities but also not allowed to work in critical sectors such as military, police, and firefighters (31).

CVD can be inherited or can be acquired throughout life as a result of neurologic or ocular diseases (32). Acquired CVD can affect a single eye, or both, while inherited CVD affects both eyes (32).

The perception of light in human vision starts from the photoreceptors cells called cones (29). There are three types of cones in which signals are analyzed and combined by the brain so that the end result yields in the observation of color. The three types of cones are long (L), medium (M), and short (S), also referred to as red, green, and blue cells (29). A healthy individual has a trichromatic vision, meaning that all three types of cones functioning in normal parameters and thus we can say that CVD occurs when a photoreceptor is malfunctioning or missing as a whole.

While there is no cure for CVD, there seems to be an emergence of improvements in terms of ophthalmic device, such as glasses and contact lenses that aid color blind people (31). While CVD does seem to disrupt color perception, it does not affect visual acuity.

2.1.5.1 Types of Color Vision Deficiencies

A classification of CVD can be done either based on its severity or the affected photoreceptors. In terms of severity, color blindness can be partial or total as such:

1. **Anomalous Trichromacy:** All three types of cones are present and functioning; however, their wavelengths are shifted and yield a narrow color spectrum.
2. **Dichromacy:** Two types of cones are present and functioning, with the third one missing entirely
3. **Monochromacy**: No cones available or just one type is present and functioning.

In terms of the affected photoreceptor cells, we can further categorize the anomalous trichromats and dichromats into three categories as such:

1. **Protanomaly / Protanopia :** The L-cone (response for red) is malfunctioning/missing
2. **Deuteranomaly / Deuteranopia :** The M-cone (response for green) is malfunctioning/missing
3. **Tritanomaly / Tritanopia**: The S-cone (response for blue) is malfunctioning / missing

It is important to note that certain CVDs can be more frequent than others. Regarding the prevalence of anomalous trichromacy in men, deuteranomaly has 4.63%, protanomaly 1.08% according to (33) and tritanomaly with 0.0002% according to (34). Dichromacies are slightly less frequent with deuteranopia 1.27%, protanopia 1.01% (33) and tritanopia with 0.0001% according to (34). Achromatopsia seems to have the lowest frequency, with 1 out of 1,000,000 men being affected according to (33). These categorizations and figures are summarized in table 2

2.1.6 Web Accessibility Guidelines

The Web Content Accessibility Guidelines (WCAG) are a set of guidelines and techniques published by the Web Accessibility Initiative (WAI). WAI is one of the initiatives of the World Wide Web Consortium (W3C) that attempts to address accessibility in websites for people with disabilities. WCAG has shaped the web design industry and has been set as a legal basis in countries within the European Union (9).

Among other initiatives set by WAI, there also resides the Authoring Tool Accessibility Guidelines (ATAG) that adress accessibility in authoring tools for the web such as Content Management Systems (CMR), XML Accessibility Guidelines (XAG) that promotes accessibility mark-up applications, User Agent Accessibility Guidelines (UAAG) that promote accessibility for user agent application such as web browsers and media players.

Table 2: A summary of the frequency of colour vision deficiencies (CVD) in men

Category CVD	Type	Frequency
Anomolous Trichromacy	Protanomaly	1.08% (33)
	Deuteranomaly	4.63% (33)
	Tritanomaly	0.0002% (34)
Dichromacy	Protanopia	1.01% (33)
	Deuteranopia	1.27% (33)
	Tritanopia	0.0001% (34)
Monochromacy	Achromatopsia	1 out of 1,000,000 men (33)

2.1.6.1 WCAG 1.0

The first version of the Web Content Accessibility Guidelines (WCAG 1.0) was released in 1999 as a W3C recommendation (35). It contains 14 guidelines - each covering a general principle to be followed and associated with one or more checkpoints. These checkpoints have assigned one of the three priority levels similar to the Moscow technique. Priority 1 states the guidelines a web developer must satisfy, which otherwise might leave a group of users unable to access information on the web page. Priority 2 states the guidelines a developer should satisfy, which otherwise might leave a group of users to find it challenging to access information on the web page. Lastly, priority 3 states the guidelines a developer may satisfy, which otherwise might leave a group of users to find it somewhat difficult to access the information.

2.1.6.2 WCAG 2.0

WCAG 2.0 was introduced in 2008 and aimed to have its guidelines be more testable to automated tools (36). In comparison with its predecessor, WCAG 2.0 is organized around four design principles of Web accessibility as such:

1. Perceivable - the content provided must be presentable to users suffering from visual impairments/-hearing loss in ways they can perceive it (braille, text to speech, etc.)
2. Operable - the functionality already present on the web page must also be made available from a keyboard, and content should be designed in such a way not to cause seizures
3. Understandable - the user interface and controls must be understandable by any users
4. Robust - the content provided via a web page must be interpreted by user agents such as assistive technology

Under these four principles fall 12 guidelines. Each guideline can be tested under 61 specific success criteria. The three levels of priority have been dropped in WCAG 2.0 in favor of three levels of compliance, A (lowest), AA (mid-range), and AAA (highest). The lower levels are a subset of the higher ones. As an example, a website that is AAA compliant also meets AA and A levels.

2.1.6.3 WCAG 2.1

WCAG 2.1 was introduced in 2018. It is to be considered an extension rather than a new version. It is background compatible with WCAG 2.0, and it comes with an additional 17 success criteria to address mobile accessibility in users with cognitive and learning disabilities.

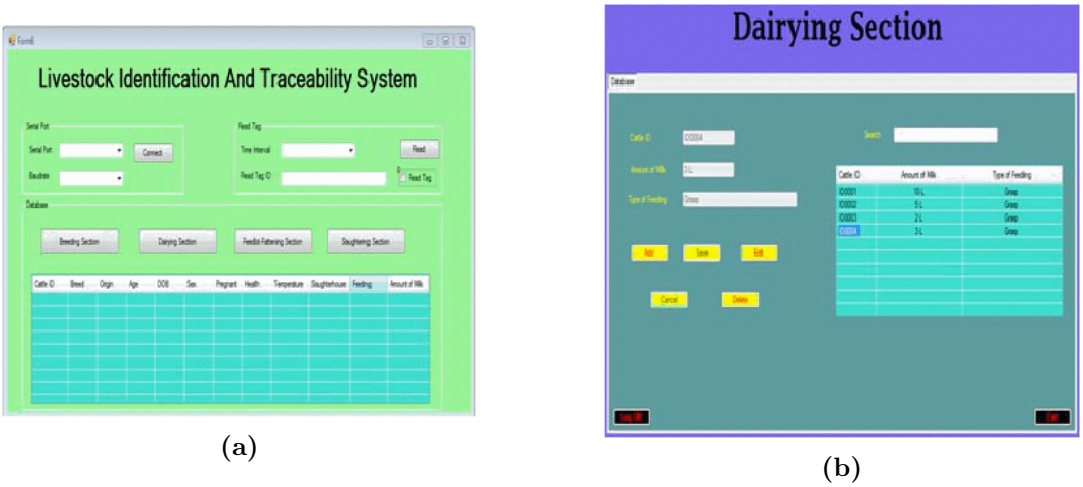
2.2 Literature Review

In the interest of finding the required literature for writing this proposal, a combination of two search techniques has been used. Firstly, *pearl-growing*, where a suite of keywords are queried on WebOfScience, ACM, Scopus, and IEEE Xplore. Keywords as *supply chain, agri-food, blockchain, decentralized applications, blockchain-based supply chains, provenance, smart-contracts, dapps* have been found to yield qualitative search results. Secondly, *snowballing* has been used as a starting point on (18) and (37) to seek for more relevant literature.

2.2.1 Related Work

Through (38), we have identified applications and dApps that had the same intent as ours, namely providing the general public with ample information regarding the product at each step through the logistical process.

(39) has created a VB.net application able to provide livestock management to farmers. This application uses RFID readers to gather information about the health status, milking output, and feedlot management analysis of individual cattle. Thus it enhances the safety and quality of the food supply chain. Figure 2 illustrates the graphical user interface (GUI) containing information regarding the livestock identification and dairying section.



(a) **(b)**

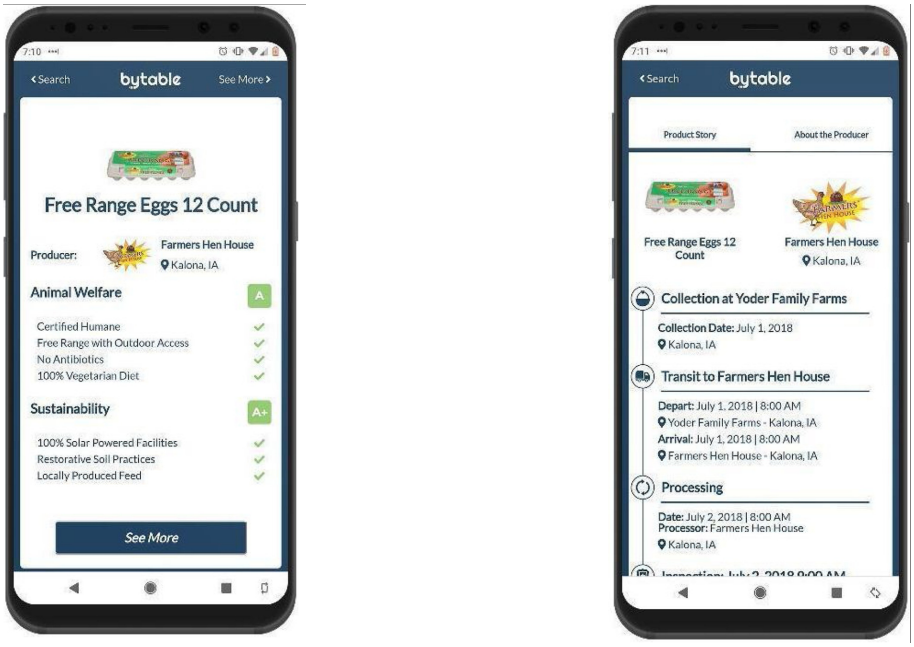
Figure 2: An example of a Graphical User Interface of a livestock management system by (39) (a) Livestock Identification and Traceability UI (b) Dairying Section UI

Moving towards dApps, we find some interesting applications of blockchain technology in the supply chain of eggs. (40) presents an egg traceability dApp pilot project tested in the United States. In figure 3, the user interface contains the product summary page and a timeline viewer. The product summary page presents information regarding the producer, levels of animal welfare, and sustainability are presented in a user-friendly way to the consumer. The timeline viewer contains an overview of the history of an egg box from farm to table.

This pilot project has been built on the Hyperledger Sawtooth, an enterprise blockchain solution developed by the Linux Foundation that uses the Proof of Elapsed Time (PoET) consensus. PoET uses a randomly generated time that decides the miner of the block, similar to a lottery system (41). PoET improves energy consumption by preventing high loads of resource utilization and enhances the transparency of the network (41).

Walmart is one of the giant retail corporations worldwide. They have been experimenting with blockchain to see how this technology would fit within their business model as early as 2016. In partnership with IBM, they went on to develop food provenance pilots to trace the origins, storage temperatures, shipping date, and expiration date of mangos and pork. Thus, they ensure food safety (5). VeChainThor is another blockchain enterprise that partnered with Walmart in 2019 to implement a mass-adopted traceability project accounting for 50% of the packaged fresh meat sold within mainland China (42). Figure 4 shows Walmart's project's general information and timeline viewer interface in the Chinese language.

VeChainThor uses the Proof-of-Authority(PoA) consensus. PoA gives authority to a small number of trust-worthy nodes to validate transactions and approve updates to the network, acting as administrators of the system (43).



(a) **(b)**

Figure 3: A web application to trace eggs by (40)
(a) Product summary page (b) Timeline viewer

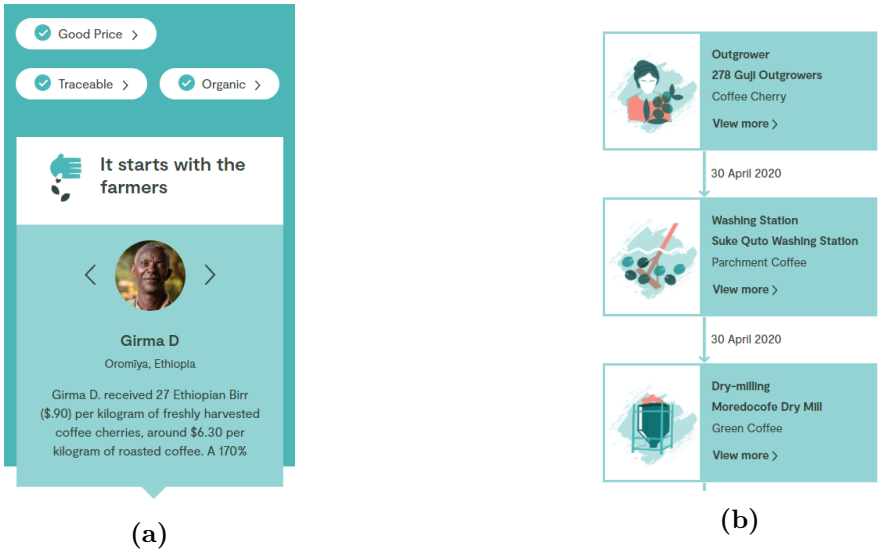
(a) **(b)**

Figure 4: Chinese Walmart dApp UI to trace provenance in their products
(a) Product general information page (b) Timeline viewer

The coffee supply chain has also seen applications of the blockchain. Dutch non governmental organizations (NGO), FairFood aims to positively impact the local farmers in Ethiopia and other entities within the supply chain by enhancing transparency. FairFood released *Trace*, a dApp that can be used to trace products from farm to fork. FairFood partners up with Trabocca Coffee to release their first pilot project on Trace. This dApp goes as far as to include the prices FairFood paid the farmers for their product. As of 2018, FairFood has tracked over 40,000 kilograms of coffee sold within the Netherlands (44). Figure 5 illustrates the user interface of Trabocca's dApp containing information regarding the product and a timeline viewer.

Trabocca's dApp is built on Topl, a blockchain solution tailored toward sustainability-focused suppliers. Topl uses a variation of a Proof-of-Stake (PoS) consensus called Taktikos that aims to enable military-grade security and a higher transaction output at a lower performance level, thus achieving a

minimal carbon footprint (45).



(a) (b)

Figure 5: Dutch dApp to trace the provenance of coffee
(a) Product information page (b) Timeline viewer

The biggest dairy company in Vietnam, Vinamilk, partnered with TrustChain in 2019 to track and trace a new infant formula through the help of QR codes on the packaging. The motivation behind this partnership seems to come from the Chinese milk scandal discussed earlier in the introduction. In figure 6, we can observe the user interface of the dApp Vinamilk has developed, containing some general information about the product and its certifications. Their dApp is built on the ecosystem of TrustChain, rebranded from the old FoodChain in 2020.

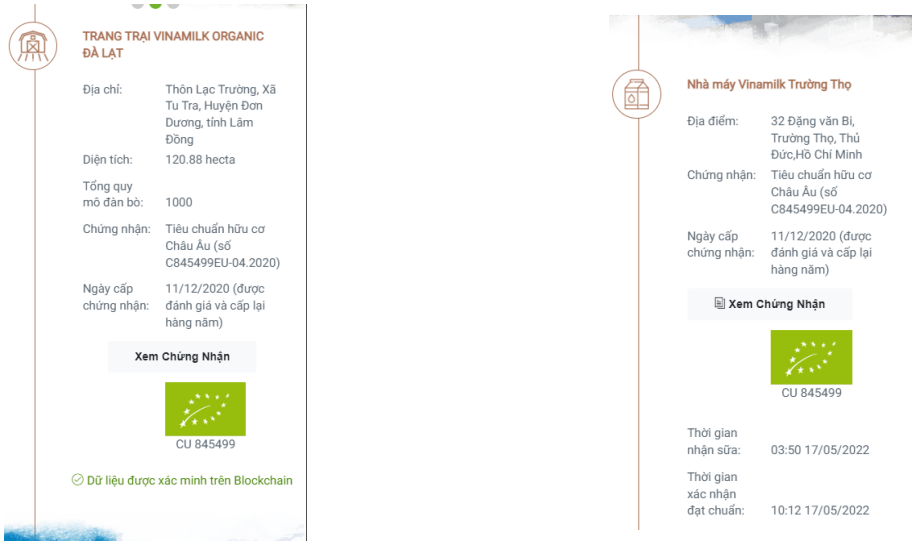


Figure 6: Vietnamese dApp to trace the provenance of dairy products
(a) Product general information page (b) Product certifications

The last related work we would like to discuss is a dApp from Swiss winemakers and can be seen in figure 7. It is developed on the Ambrosus blockchain and is designed for Internet-of-Things data and

supply chain provenance. Ambrosus build on top of the Ethereum blockchain as a Layer 1 (L1) solution and uses the PoA consensus, as explained earlier. ZIMT takes care of certifying the data and creating a QR code for each bottle of wine produced.

Figure 7: Swiss dApp for tracing the provenance of wine

2.3 Comparison with related work

In this subsection, we make a comparison of our proposed solution with the related work within the field as explained in subsection 2.2.1. Firstly we investigate the underlying technology of each, and successively, we discuss some of the features contained in them.

- **Blockchain Technology:**
  In terms of blockchain technology, all related are built on different networks. The egg traceability project implemented in (40) makes use of the Hyperledger Sawtooth, Walmart uses VeChainThor, Trabocca uses Topl, Vinamilk uses TrustChain, and lastly, the Swiss dApp for tracing wine uses Ambrosus, which is part of the Ethereum blockchain. Although each technology is unique at its core, they try to serve the same use case that is providing as much information as possible at any point during the supply chain lifecycle.
- **Network Consensus:**
  Two of the dApps use the PoA consensus, namely Walmart and Swiss Wine, PoET is used by (40), and Trabocca uses PoS. Unfortunately, we have not been able to find more information regarding the network consensus of TrustChain, used by Vinamilk.
- **Internationalization:**
  When it comes to the internationalization of the related work, the dApps for Swiss Wine, eggs, and coffee are available in the English language. Meanwhile, the Walmart and Vinamilk dApps are available only in the local language, namely Chinese and Vietnamese, respectively.
- **Level of WCAG compliance**
  To check the compliance of each dApp, we have used an automatic tool available at (46). The results are quite unsatisfactory, yielding to the conclusion that none of the dApps are Level AA compliant.
- **Presence of accessibility features**
  Each dApp has been used extensively to check the Presence of accessibility features. The conclusion we have derived is that in none of them it is possible to change the text size, colour scheme, or language as described by WCAG standards explained in 2.1.6.

- **Responsiveness**

  To check the responsiveness of the dApps, we have used Chrome's developer console to change the size of the screen and thus mimicking a vast amount of resolutions. We found out that the dApps of Vinamilk, Trabocca, SwissWine, and ByTable are quite responsive and react well in both desktop and mobile resolutions. On the other extreme, Walmart's dApp does not seem to respond so well on the mobile platform and rather just focuses on the desktop experience.

- **Performance**

  The performance of the dApps has also been analyzed. An important notice is that both Walmart and Vinamilk dApps have their servers located in Asia, and thus the round-trip time to make a request is significantly larger. Having said this, we have measured the performance in the time it takes the paint the content in the DOM after the data has been fetched so that we do not take into account the position of the servers. Our findings show that Trabocca, SwissWine, and ByTable have the best performance, while Walmart and Vinamilk perform significantly worse.

These findings are summarized in table 3. We arrive at the conclusion that our proposed solution will further enhance the accessibility features lacking in all the other dApps and on the overall user experience.

Table 3: A comparison of the related work and our proposed solution

Aspect \ dApp	ByTable	Walmart	Trabocca	Vinamilk	SwissWine	TracingLens
Blockchain Technology	Hyperledge Sawtooth	VeChainThor	Topl	TrustChain	Ambrosus	Not Applicable
Network Consensus	Proof-of-Elapsed-Time	Proof-of-Authority	Proof-of-Stake	Not Applicable	Proof-of-Authority	Not Applicable
Internationalization	×	×	×	×		✓
Compliance level	A	A	A	A	A	AA
Accessibility Features	Limited	Limited	Limited	Limited	Limited	Abundant
Responsiveness	Fair	Limited	Fair	Fair	Fair	Excellent
Performance	Good	Bad	Good	Bad	Good	Good

3 Methodology

This section intends to describe the methodology used in the implementation process of our proposal. With the current literature research we aim to make a solid foundation on the most suited framework to develop our application, such that it is available to an audience as broad as possible.

Throughout the research and implementation stage, we will be using using two methodologies. The first one is *Design Thinking*, a model proposed by Stanford and University of Potsdam, as seen in figure 8, and further discussed in detail in subsection 3.1. Design Thinking is an iterative and non-linear process consisting between 3 to 7 stages, used frequently within the Computer Science field (47). It The second methodology adopted while designing our User Interface (UI) is Atomic Design (48), as discussed in 3.2. The reasoning behind this stands in its ability to offer us a way to increase maintainability and scalability.

Thereafter, diving into the more practical direction, our application will be built using the Angular front-end framework. Ionic will be used for some native functionality and UI components. The data will be fed from Firestore Database, a scalable and flexible NoSQL solution developed by Google.

As a source-code editor, Visual Studio Code will take preference for its extensive developer tooling and debugging abilities.

As a choice of version control, a private GitHub repository will be used in combination with different pipelines in place. As continuous integration and testing pipeline, Travis CI will be used to ensure security and mitigate risk. Additionally, Github Actions and Firebase Hosting will be used as a continuous deployment tool to package and deliver the application code for each Pull Request (PR) made.

To answer our research questions, we will use a combination of both automated and manual evaluation. In the automated evaluation we will use some tools to check on the performance, accessibility and best practices of the application. In the manual evaluation we will conduct a statistical analysis.

The research paper will be written in Overleaf, an online editor for LaTeX, in order to maintain a scientific aspect. Any changes done will be automatically backed up on GitHub to prevent potential data loss. All work commenced towards the bachelor project will be done solely on personal computers.

3.1 Design Thinking Process

Design Thinking is a methodology in which designers solve real-world problems by researching the users' needs, exploring potential solutions, and testing them out. The ideology is that if the designer adapts his mindset to better understand the problem as seen by the user, the solutions will be found easier. This is why it is reasoned to be, at its core, human-centered. The origins of the term design thinking are around the time when research started to be done in the 1950s around creativity techniques. It was then adopted by (49) in 1980 to address "wicked problems" in regard to architectural design. In 1987, (50) further expanded the term with methods adopted by architecture and urban planners. Since then, more applications have been found in education (51), business (52) and Computer Science (47). In the latter one, design thinking has drastically changed the way we use computers through improvements to the User Interface (UI) and User Experience (UX). In the next subsections, we will cover the stages of DT and how it was used to structure our thought process in implementing the application.

3.1.1 Stages of Design Thinking

DT has anywhere from 3 up to 7 stages depending on the field where it is used. For a successful implementation of our dApp, we will use the six stages model proposed by Hasso-Plattner-Institute at the University of Potsdam, Germany, and Stanford, illustrated under figure 8.

These stages do not necessarily fall in order, and they can be iterative.

1. **Understanding** - is the stage where research is done to know more about the problem. Gaps are filled, and a problem statement is defined.

   Following the brief literature review preceded in section 2.2, we can indeed say that we understood the problem.

2. Secondly, **Observing** is where the user needs and desires are mapped out

   Our primary users will be regular people that would like to know more about the provenance of what they consume. The secondary users are government entities tasked with maintaining a high

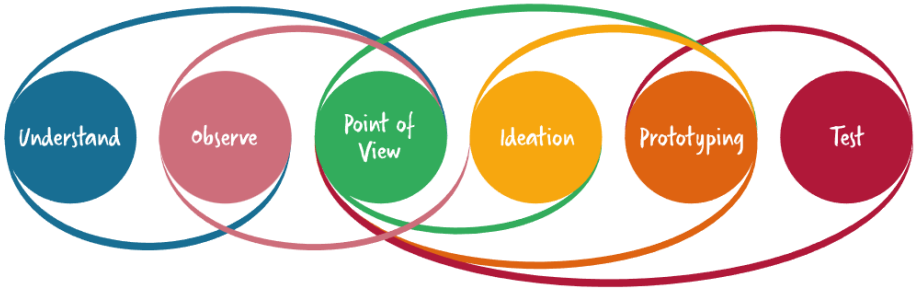


Figure 8: The Hasso-Plattner Design Thinking Model
Available from
`https://hpi-academy.de/en/design-thinking/what-is-design-thinking/`

regard for food safety. Producers and merchants are also part of this category, which rely on the application to check the progress within the lifecycle of the supply chain process. The tertiary users are the application developers tasked with maintaining and adding further improvements to the ecosystem.

3. In the phase **Point of View**, the problem statement and insights gained will be summarized, and the point of view reframed.

   Following the past two stages, a meeting was held with both supervisors of this thesis to discuss the research results. Multiple insights were clustered, and different points of view were synthesized.

   Since we would like to make our application available to the broadest audience possible, we need to consider the language barrier, age of the user, demographics, and impairments that could impact the application's application.

   Users' personas were defined based on research and observations to get a deeper understanding of their needs, behaviors, and motivations. This allowed us to prioritize features based on human-centric value rather than business value. We have also followed the rule of designing for the primary and accommodating the secondary.

4. **Ideation** is where the problem is faced from different points of view such that a variety of possible solutions can more easily be found. From here, the best idea is picked and goes to the next stage.

   Starting from the original problem statement, we have thought of applications for iOS, Android, Windows, and Web to be possible solutions. Analyzing the strengths and limitations of each made us choose to implement our solution as a web application. Through more research, as will be explained in 4.2,the framework of the front-end has also been chosen.

5. **Prototyping** is where concepts are visualized. They can range from low fidelity (drawings, wire-frames) to high fidelity prototypes, which are more interactive and functional. It is important since it allows a batch of users to test the solution and its quality and therefore achieve human-centeredness.

   The first sketches for our application can be seen in figure 9. We then further improved by evolving the sketches into wireframes, as seen in figure 10. Lastly, based on the gathered feedback from the wireframes, we went on to develop the high-fidelity prototype as seen in 11. Furthermore, we developed the rest of the application in the chosen front-end framework using the Atomic Design methodology, as described in 4.

6. **Testing** is where the proposed solution is rigorously tested for vulnerabilities.

   Throughout this stage, the most important aspect is to validate our solution. A survey was conducted to verify on the satisfaction and correctness of our proposed solution. The design of the survey can be found in subsection 5.2. The results are discussed in subsection 5.3.

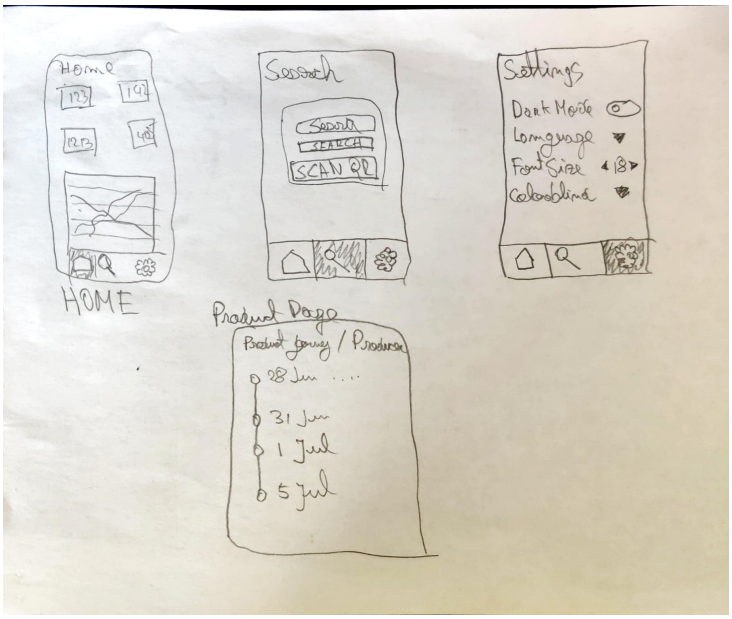


Figure 9: Initial sketch of our proposed solution

Figure 10: Evolved wireframes from sketches
(a) Home Page (b) Settings Page (c) Search Page
(d) Scanning QR Code (e) Product Journey (f) About Producer

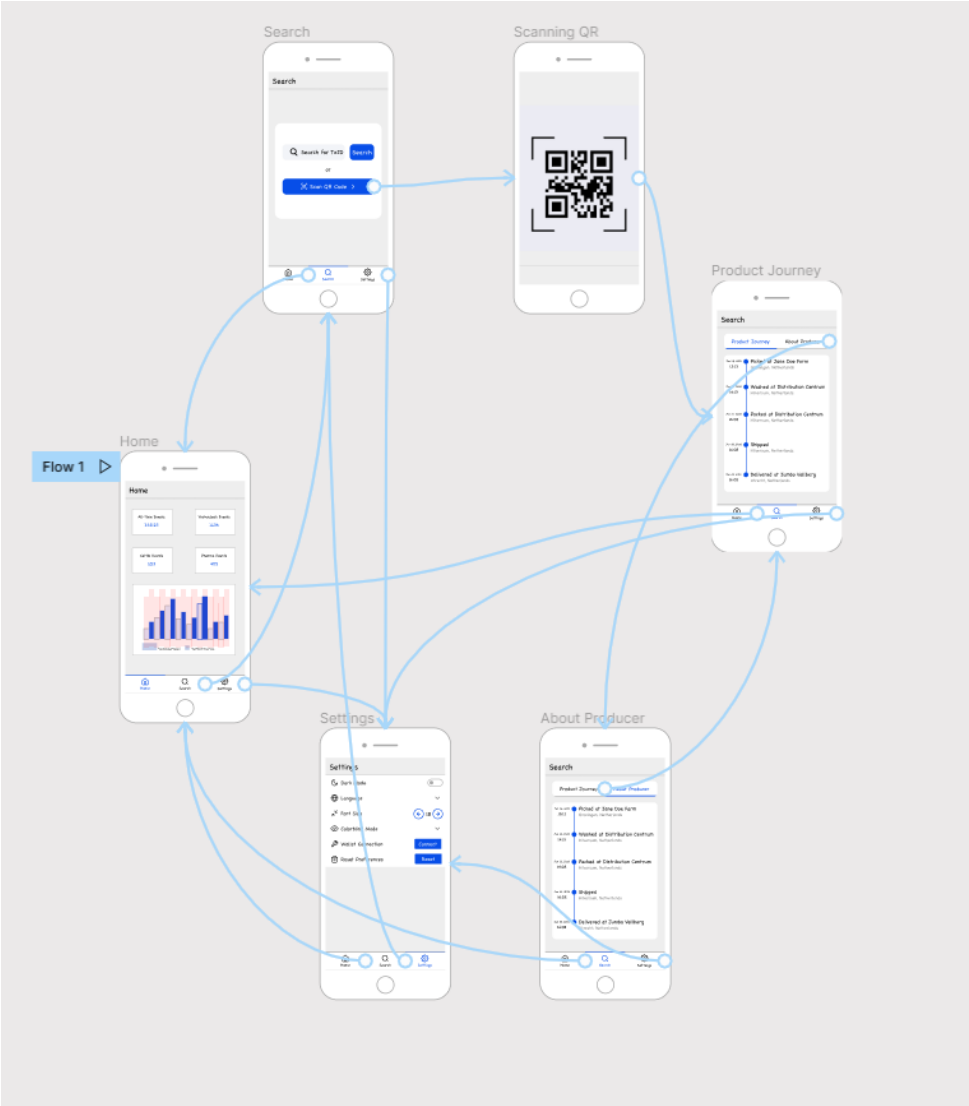


Figure 11: High fidelity prototype from wireframes

3.2 Atomic Design Methodology

Atomic design (AD) is a web design methodology developed by (48). This methodology is inspired by the composition of matter, just like in Chemistry. On its own, each chemical element has distinct properties. They can have a different density, boiling point, state (liquid, gas, or solid), or amount of protons. When two atoms of Hydrogen and Oxygen have combined, a molecule of water as we know it is created. This process of combining atoms or smaller elements together to create molecules or groups of elements can also be used while designing our UI. By doing so, we achieve scalability and reusability, both being important aspects of Computer Science. The stages of AD are nextly discussed.

3.2.1 Stages of Atomic Design

The Atomic Design contains five distinct stages, as seen in figure 12, with each building on top of the previous ones. Similar to DT, AD is also non-linear.

1. **Atoms** - just as in Chemistry, represent the foundational blocks comprising our User Interface. They can be labels, selectors, buttons, icons, and other small HTML elements that cannot be separated further without ceasing to function. In figure 13, examples of atoms within our UI can be observed.

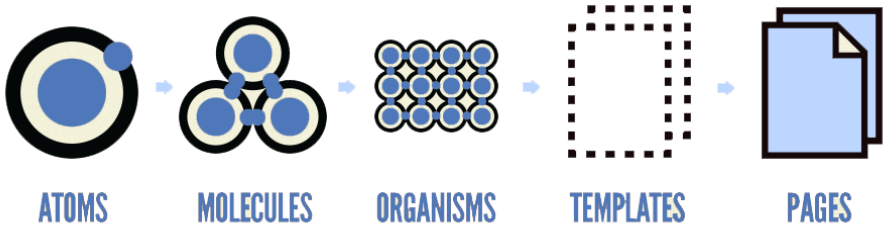
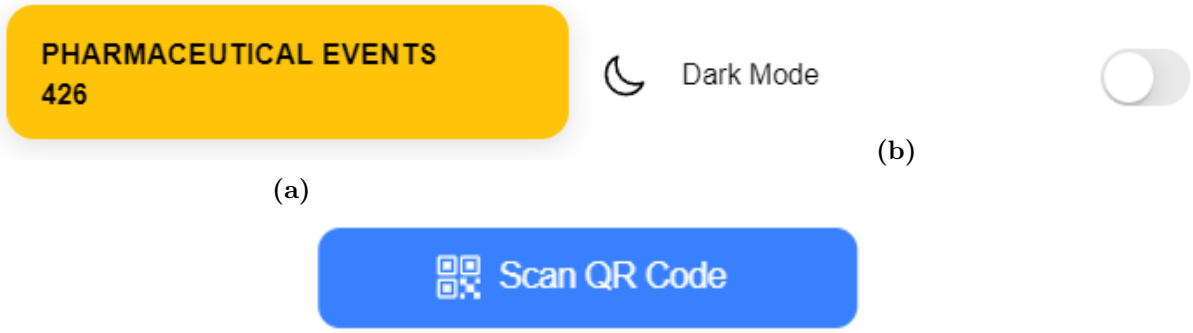


Figure 12: Atomic Design Methodology Stages Overview. Image from (48)

(a) **(b)** **(c)** **(d)** **(e)**

Figure 13: Examples of atoms within our UI
(a) Button (b) Icon (c) Pill (d) Toggle (e) Label

2. **Molecules** - are combinations of two or more atoms, with each having its unique properties, format, and style that work together as a unit. By crafting the atoms first, and the molecules second, we achieve a simplicity that allows us to test and adapt our UI to further changes much more effectively. Another benefit worth mentioning is the bonding to the Single Responsibility Principle (SRP), which states that "a module should be responsible to one, and only one, actor" (53). In figure 22, some molecules within our UI are shown. For example, in 14c, the molecule responsible for starting the action of scanning the QR Code is composed of a button, label, and icon.



(a) **(b)** **(c)**

Figure 14: Examples of molecules within our UI
(a) Number of pharmaceutical events (b) Dark Mode Toggle (c) Scan QR Code Button

3. **Organisms** are the next stage in the AD methodology and the last, which is related to the chemistry world. They consist of simple molecule groups that together form a more complex structure that can be reused in distinct sections of our UI. In figure 15, an organism used for searching is represented. It is composed of two molecules, a scan QR code button, and search input. On top of this, there are also molecules such as labels and images.

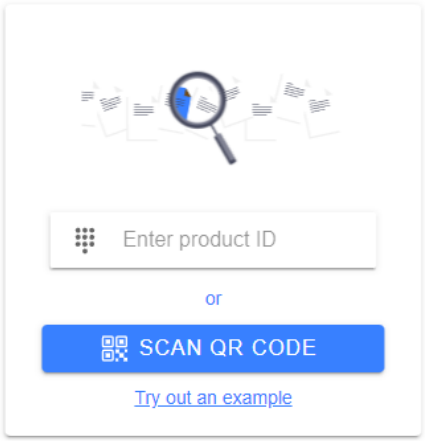


Figure 15: An example of an organism

4. **Templates** are the places where organisms, molecules, and atoms are combined together into a specific layout and cohesive design. They are considered to be more of a blueprint for the fully-finished pages and show where the molecules/organisms are placed in a contextual way. An example of such a template can be seen in figure 16. It does not contain real data and instead relies on a dummy one to account for the dynamic nature of our data.

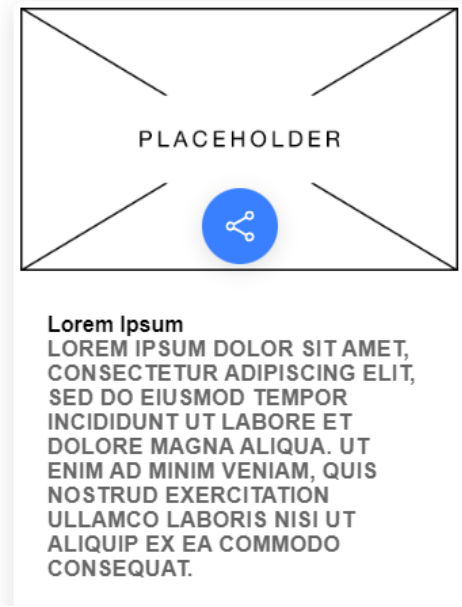


Figure 16: Template of livestock

5. **Pages** are the last stage within AD. They are instances of templates filled with real/purposeful data and capture what the final UI should be seen as — by the actual users. It is at this moment where we can gather feedback on the aesthetics and the functionality of our application but also test the robustness of our UI. Building on the previous example in figure 16, we can now see how the final page for livestock should look like in 17

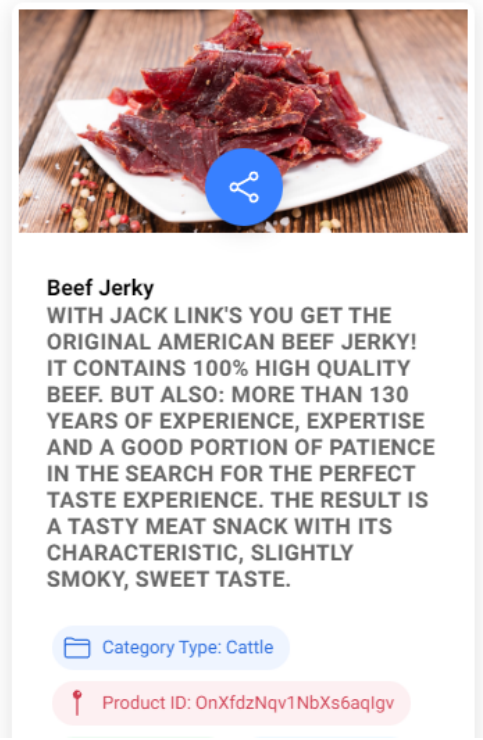


Figure 17: Page of livestock

4 Software Design & Implementation

In this section we discuss details and motivate choices that were made throughout the design and implementation process of the application such that it is serves a broad audience.

4.1 Choice of Web Framework

In order to make an adequate choice when it comes to the framework of the front-end, we do not only need to think about the application's goals in the present but also about the features that could come after this bachelor project is finished. Therefore, maintainability and upgradeability are considered to be quite important. Based on (54) and personal observations, the following criteria seemed to be important.

Programming Language

The programming language a web framework comes with is an important aspect we should take into consideration. While there seems to be an abundance of programming languages, not all get to maturity to be used for commercial purposes. They can differ in features and level of abstraction; thus, the possibilities can be limited if the idea of the project has a higher complexity than average. Some are faster, and others are more robust. Programming languages can be either interpreted and processed at runtime or compiled into machine code. In an interpreted language as JavaScript, each line is fetched, decoded, and executed. This iterative process can lead to long execution times. Compiled programming languages typically have a better performance than interpreted ones.

Learning Curve

Hermann Ebbinghaus, a German psychologist, invented in 1885 the concept of a "learning curve" (55). This concept refers to how fast can an average person complete a task or learn a new skill. Herman's intention was to prove that depending on an existing area of expertise or background, some people could

learn faster or slower than others. In Computer Science, this concept is usually referred to as the ability to master a new programming language in the shortest amount of time.

(56) has come to the conclusion that if a task is repeated as much as possible, then the time required to perform it decreases as well. Based on this assumption, we can interpolate it to the Computer Science field and say that programmers that have experience in similar languages have a certain advantage over those who have not and that personal experience should be taken into account when making a choice. Each framework comes with its own rules and conventions. Some are more similar between them than others. In general, the steeper the learning curve is, the more time spent to get more familiar and get the job done increases exponentially. Another important notice is that the learning curve is subjective for each individual. It ultimately comes down to the preference and existing knowledge of a developer.

Documentation Level

In the Computer Science field, software documentation is an important set of instructions that aid the development process. It typically contains information on how to install, use it and troubleshoot if necessary. It can include documentation related to requirements, which specify how the software should perform, or information related to architecture, which emphasizes how the components work in harmony with each other.

By having adequate documentation, the developers can get more familiar with the software used and therefore lower the impact that it has on the learning curve.

Developer Community Size

Another important aspect when picking up a framework is the community of developers around it. If the size of it is large, then so will the amount of information found on the internet that could assist in the implementation process. According to (57), community engagement is associated with a bigger developer team size. And therefore, with a bigger developer team size comes an assurance that the framework will be maintained and receive updates in order to adhere to modern-day standards. In table 4, it can be shown that Angular has the most amount of contributors, React comes exceptionally close in the second position, and Vue is last. When it comes to the weekly downloads on NPM, React is by far the most popular one, Vue being second and Angular last.

Table 4: A comparison of Javascript front-end frameworks popularity in August 2022

	Angular	**React**	**Vue**
Github Contributors	1,607	1,565	339
Github Stars	83,221	193,213	199,921
NPM Weekly Downloads	2,958,738	16,106,034	3,328,549

Data Binding

Data binding is a technique that connects and synchronizes data between the app's internal state model and the consumer's view of that state. This can be done one-way, meaning that the information can pass from the model to the view, or two-way, meaning that the information can pass from the model to the view and vice versa. Each method has its advantages and disadvantages. One-way binding causes fewer conflicts when using multiple sources of data. Using two-way binding might result in unexpected states of the model. In the grand scheme of things, though, this ability to process information simultaneously can lower the lines of code written by the developer, thus, simplifying the complexity of the final product.

4.2 Framework comparision

In this subsection, we make a comparison of the top 3 most popular frameworks in front-end development introduced earlier in the paper. Based the aspects that were deemed important discussed in subsection 4.1, and (54), we will make a selection on the most appropriate front-end framework to start developing our application.

In terms of programming language, TypeScript has a certain advantage over JavaScript because of its static type-checking abilities. TypeScript also has support for classes and modules, and thus higher-complexity projects can be achieved. All three frameworks are developed by giants within the industry and thus are able to create good documentation standards. Hence why, we treat them equally in this regard. When it comes to the size of the developers' community, Angular and React are head to head, and Vue is coming in third. When it comes to synchronizing data between the model and the view, Angular and Vue are similar in this regard and can achieve it in a hybrid manner, while React can only fulfill it one-way only. Lastly, junior web developers seem to pick up faster React and Vue applications due to their moderate learning curve.

These aspects are summarized in table 5. For the therefore mentioned aspects, we arrive at the conclusion that Angular is performing overall better in all aspects. Taking into consideration upgradeability and maintainability after the bachelor project is done, Angular is also the most appropriate option to achieve that. Thus, it was decided that Angular is the best framework to implement an application in tracking provenance to a wide audience.

Table 5: A comparison of front-end frameworks

Aspect \ Framework	Angular	React	Vue
Programming language	Typescript	JavaScript ES6	JavaScript ES6
Developed by	Google	Facebook	Vue Technology
Learning curve	Steep	Moderate	Moderate
Documentation level	Good	Good	Good
Community size	Huge	Huge	Medium
Data Binding	One-way/Two-way	One-way	One-way/Two-way

4.3 Database Design/Model used

The database which holds the data that our application uses is a Google Firestore instance. Firestore is Cloud-as-a-Service (CaaS), NoSQL database. It synchronizes the data in real-time for every connected device to our dApp. The data is stored in documents, which in turn are organized into collections. In figure 18, it can be observed how data is organized within Firebase.

A document containing a set of key-value pairs is treated similarly to JSON but supports additional data types, which will be covered shortly. In figure 19a, it can be observed one such example that is used in the application. Documents are identifiable by a unique name, either system-created random IDs or user-generated. Documents can in turn contain complex nested objects which is also our case for timeline_collection, observed in 19b.

4.4 LMS Daltonization

The LMS Daltonization algorithm was used to change the colour scheme of our dApp for users suffering from Colour Vision Deficiency (CVD). It was originally coined in (58) and its name comes from the color space representing the sensitivity of the three types of cones within the human eye, namely long (L), medium (M), and short wavelengths (S). It is one of the most famous algorithms when it comes to emulating colours as seen by people with Protanopia, Deuteranopia, and Tritanopia. Another important application of this algorithm is *daltonization*, the process of converting colors to be more perceivable to CVD people. (59) comes as an improved version performance-wise of the original method and introduces an error matrix for Protanopia. (60) further improves upon (59) by adding error matrices for Deuteranopia and Tritanopia. In the next section, we will briefly explain how the LMS algorithm works, how we implemented it, and the results obtained.

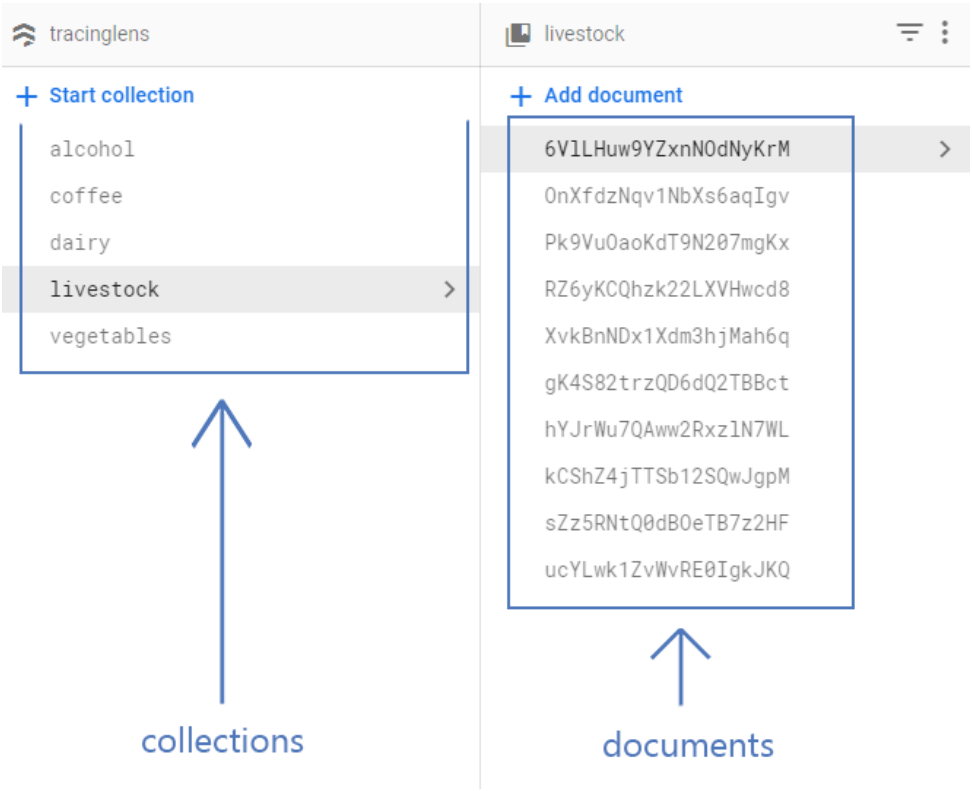
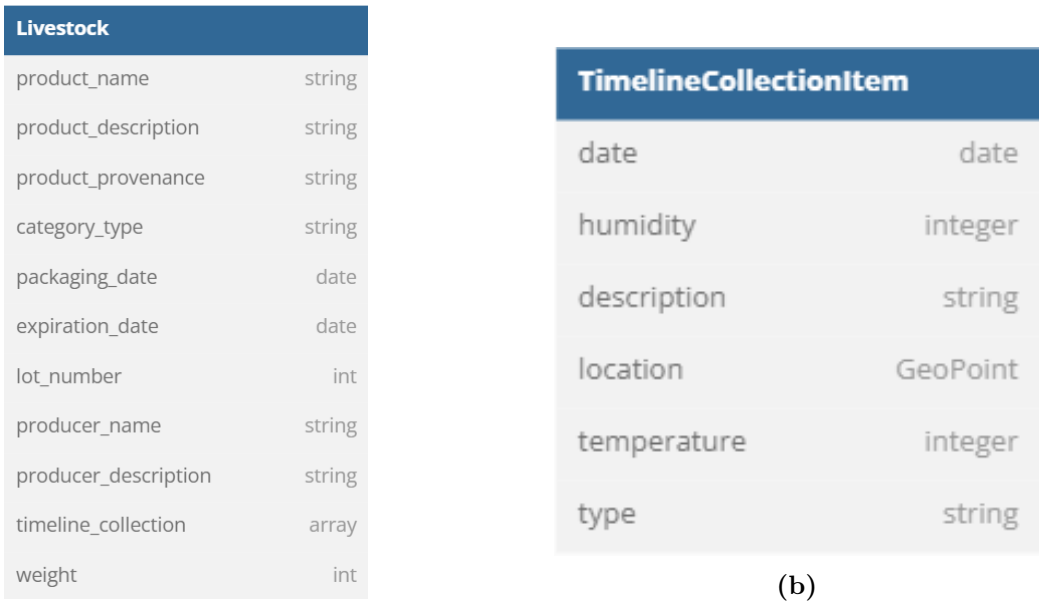


Figure 18: The organization of data within Firebase



(a) (b)

Figure 19: Models within Firestore
(a) Model of the collection 'livestock' (b) Model of TimelineCollectionItem

4.4.1 Implementation

It is important to note (59), (60) are meant for daltonizing images. To better fit our use case, we have adapted (60) by removing its iterative behavior and making it work only for pixels. The adapted algorithm can be found in 1.

As choice of programming language, Python, has been used to implement LMS Daltonization, the

Algorithm 1: LMS Daltonization algorithm based on (60) and modified to work only on pixels
Input: RGB Pixel
Output: CVD corrected RGB pixel

1 Define the RGB colour to be corrected
2 Convert the RGB colour to LMS
3 Simulate LMS color for each type of colour-blindness
4 Convert back to RGB the simulated LMS colors
5 Calculate the difference between the original and simulated colour blindness pixels.
6 Shift the differences towards the visual spectrum by multiplying with the error matrices
7 Add the shifted differences with the original RGB colour. The result is the original RGB color daltonized

source code for it being available in appendix A

4.5 Daltonization of colour scheme

After running the Python algorithm on our Level 2 (AA) compliant colour scheme, the results can be found in figure 20. It is important to note that for the purposes of our implementation, the daltonized colour scheme can be used both for dichromats and anomalous trichromats.

Furthermore, with the new colour schemes in place, the notification layout has also been changed, as seen in figure 21.

Client satisfaction results are presented later in subsection 5.3.4, where the respondents report their satisfaction with the accessibility features of our application.

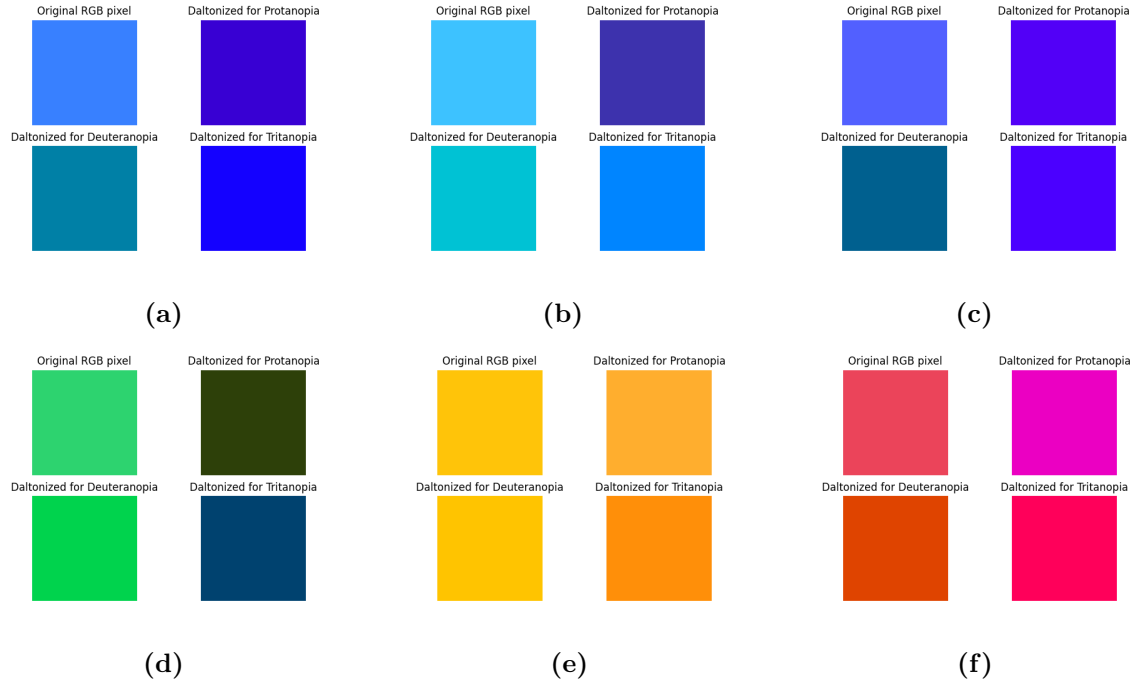


Figure 20: Daltonization of colour scheme
(a) primary (b) secondary (c) tertiary
(d) success (e) warning (f) danger

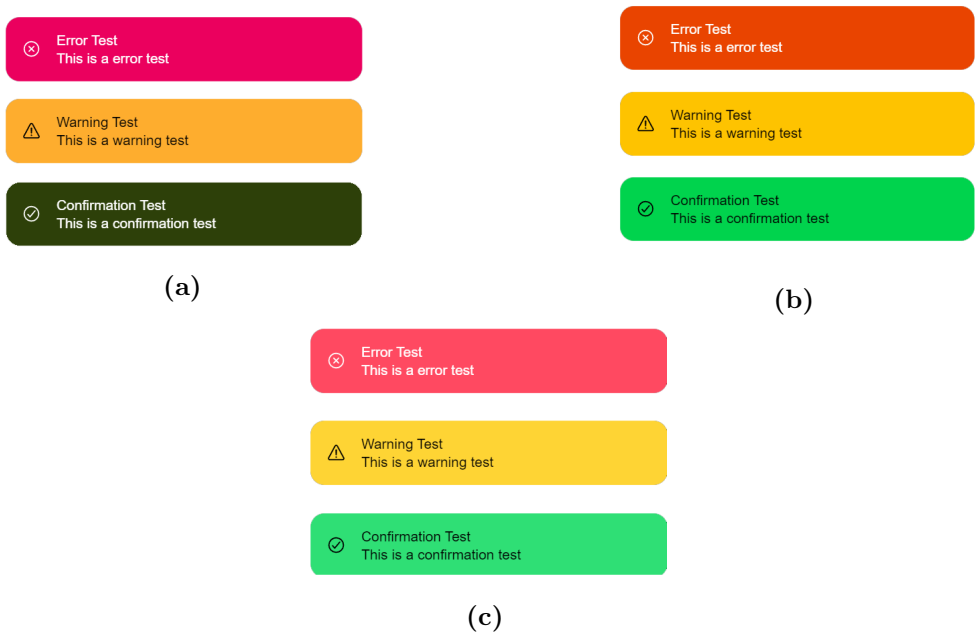


Figure 21: Daltonized color scheme for notifications
(a) Corrected for Protanopia observer (b) Corrected for Deuteranopia observer
(c) Corrected for Tritanopia observer

4.6 Internationalization

Currently, our application is available in the following languages: *English, Dutch, German, Romanian, Italian, Finnish, Russian, Chinese and Arabic*. This has been achieved thanks to a handful of volunteers. To ensure the high standards of internationalization, this had to be acquired two ways, namely, manually and automated translation. The *hard-content*, which never changes it state should be manually translated for accuracy reasons. The *dynamic-content*, which changes its state quite frequently depending on the content of the data fetched from the database, must be translated automatically. Nextly, we discuss the language format supported within the application and how it was implemented.

4.6.1 Language Format

For each language supported by our application, a corresponding entry of it must exist within the configuration file loaded in the initialization step of our dApp. In addition to this, another JSON file representing the translated strings used throughout the app must exist. In table 6, the data format of a language can be observed.

Table 6: The data format of a language

Property	Type	Description
name	String	The name of the language, which will be shown in the language selector
flag	Unicode	The Unicode emoji which will be shown on the left of the language name
value	ISO-639-1	The language code value represented in ISO-639-1 standards
Dir	ltl/rtl	The direction in which the content unfolds

4.6.2 Manual translation

For manually translating our application, we have used the ngx-translate Angular library available at (61). ngx-translate gives access to a service that can be used to serve pre-defined translations. It also allows the switching of languages quite easily at runtime without the need for a refresh. In listing 1, we

can see how the pre-defined translations look like in the English language. On the left-hand side of the colon **:** reside the ids' and on the right side, the translation text of the content.

Listing 1: Example of manually translated strings in English

```
{
  "ERROR": {
      "ERROR-HEADER": "Error",
      "CONNECTION-ERROR": "Connection error",
      "SCANNING-ERROR": "Scanning error",
      "CAMERA-NOT-FOUND-MESSAGE": "A camera could not be found",
      "NOT-FOUND-ERROR": "Not found. Please scan a compatible QR Code",
  }
  ...
  "NOTIFICATIONS": {
    "close": "Close",
    "change-network": "Change network"
  }
}
```

4.6.3 Automated translation

For automated translation, we have used the Cloud Translation API developed by Google (62). It uses a pre-trained machine learning model to translate content into more than 100 languages. This model is updated from time to time when new training data or better techniques become available.

5 Evaluation

In this section we discuss the evaluation. To ensure our application abides by the best practices and that is Level AA compliant, we have adopted a combination of two evaluation techniques. The first one uses automated tools to check for errors, vulnerabilities and guidelines not being respected. The second, its composed of a survey which goal is to gather feedback on the correctness and satisfaction on the application. Ultimately, we answer the research questions.

5.1 Automated evaluation

For the automated evaluation of our application, we have used a number of tools such as Lighthouse and Wave. Nextly we explain what these technologies are and discuss their results after being run on our application.

5.1.1 Lighthouse

Lighthouse is a tool that automatically measures the performance, search engine optimization (SEO), and quality of web pages. Among these features, it is also able to audit web pages if they abide by best practices in accessibility. Nextly, we discuss the results of Lighthouse on the therefore-mentioned aspects.

- **Performance**

  In terms of performance, our application has scored 90 points out of 100, as seen in figure 22a. Performance is a quite significant aspect when it comes to user retention. (63) found that 53% of visitors abandon the website if loading takes more than 3s. The first content is painted in the DOM 1 second after it is loaded, and the time for the application to be interactive is 1.2s. This is in comparison with the 15.3s average load time for a mobile page on 11 million web domains in a study conducted by Google (64), we can safely say that our application performs much better than the average.

- **Accessibility**

  In terms of accessibility, our application has scored the maximum score of 100, as seen in figure 22b. The pages have a logical tab order, and therefore, screen readers cannot read elements that are offscreen. The custom interactive controls are keyboard focusable and display a focus indicator. When new content is added to the page, such as a dialog, the focus of the user is directed to it. Associated labels and ARIA roles have also been added to custom controls. All of the therefore mentioned are guidelines of WCAG 2.0 as described in 2.1.6

- **Search Engine Optimization and Best Practices**

  In terms of search engine optimization (SEO) and best practices, our application has scored 80 and 100 points, respectively. Both scores can be seen in figure 22d and 22c. On our hosted domain, we have a strong content security policy (CSP) which significantly reduces the risk of cross-site scripting (XSS) attacks. Even though our application does not handle sensitive data, we have used HTTPS to tunnel communication, a much more secure internet protocol than the standard HTTP.

A detailed report can be found in appendix D

5.1.2 WAVE

WAVE is a tool that helps web developers make their work more accessible for individuals with disabilities. It is available as browser extensions for Chrome, Firefox, and Edge and can also be used online by just typing the website wished to be checked (65). By identifying accessibility and WCAG errors and fixing them if necessary, our intent is to facilitate human interaction on our web application.

After running WAVE on our application, the results were 0 errors, 0 contrast errors, and two alerts. The results are summarized in figure 23

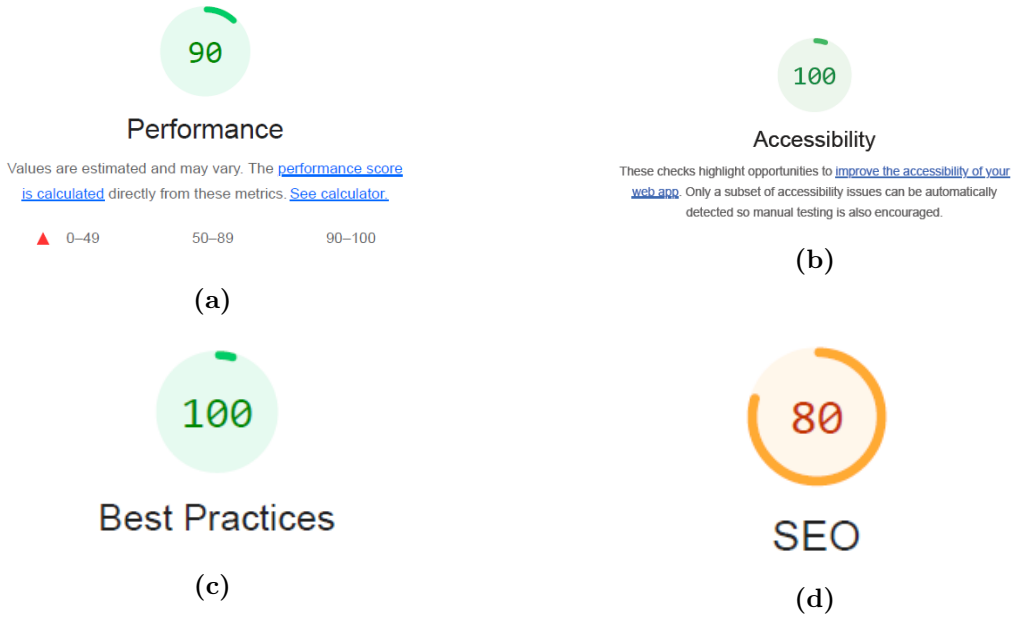


Figure 22: Automated evaluation scores of Lighthouse
In terms of (a) Performance (b) Accessibility
(c) Best Practices (d) Search Engine Optimization (SEO)

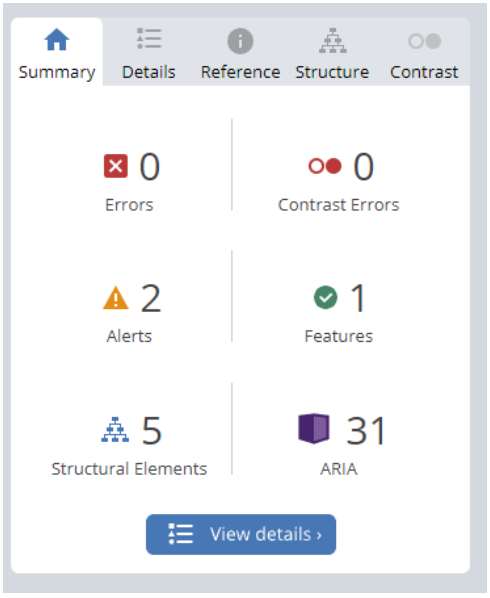


Figure 23: Automated evaluation summary of WAVE

5.2 Survey Design

In order to assure the quality of our implementation and to know more about the problems that visually impaired users face while using our application and technology in general, we have employed a survey that consists of 35 questions separated into six sections as such: control variables / demographics, accessibility issues of the respondent, usage of our application, satisfaction of accessibility features and gathering feedback to improve the overall experience of the application. The questions and the format of the survey can be studied further in appendix B.

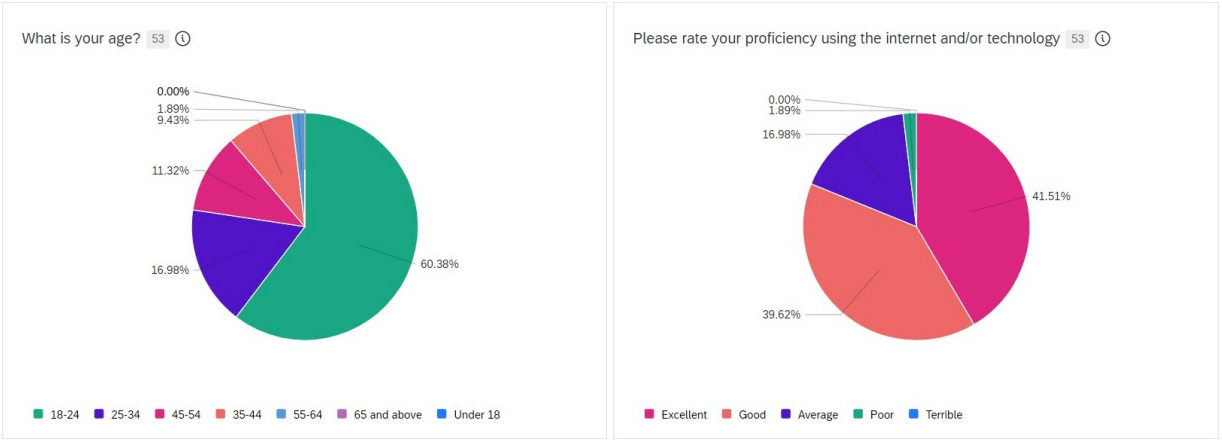
The survey has been designed with conditional questions which require the respondent to have answered positively to a previous question (e.g., gathering feedback on the implementation of the daltonized colour scheme is not enabled if the respondent did not indicate they suffer from CVD). The questions

that assess the accessibility problems of the respondent are inspired by a survey conducted by WebAIM (66) and thus enforce the validity of our study. The survey has been promoted in LinkedIn and Facebook groups tailored to visually impaired users but also in various WhatsApp groups of University students.

5.3 Survey Results

The survey has been open for responses starting from the 1st of August till the 15th of August 22 and has gathered 122 responses, out of which 53 were completely finished. In figure 24a, it can be shown that 60.38% of our respondents are between 18-24. The next largest segment is 25-34 and contributes to 16.98% of the respondents. Figure 24b shows that 41.51% and 39.62% of our respondents have self-assessed their proficiency in using the internet and technology as excellent and good, respectively. Therefore, we conclude that our respondents are represented by the younger generation that pertains a good proficiency in internet and technology.

More than 75% of our respondents have indicated that knowing the provenance of an aliment is important. Out of the 53 respondents, 6 of them indicated that they suffer from CVD, and 24 have said they have moderate vision, and thus, the use of a computer is generally facilitated by using correction (e.g., glasses, contact lenses). In terms of assistive technologies, 31% have indicated the use of browser zoom controls such as pinching in and out, 13% use high contrast mode or dark theme, and 10% use tools that highlight text as it is read.



(a) **(b)**

Figure 24: Demographics of survey respondents
In terms of (a) Age (b) Self-assessed proficiency in using the internet and tech

5.3.1 Research question

We have employed a research question aimed at offering insight into the factors that determine a respondent's satisfaction. Therefore, using the accessibility of the application, proficiency in using technology in general, and blockchain technology in particular, as our independent variables, we will analyze the effect they have on the satisfaction of the individual surveyed. We conclude by phrasing our research question as follows: *To what extent does a high level of accessibility provided by the application and a high level of user proficiency lead to increased levels of satisfaction?*

Naturally, the research question encompasses the two independent variables, accessibility and user proficiency; both are assumed to positively impact on the dependent variable satisfaction. As the features aiding individuals with visual impairment are explicitly created to improve the user's experience, we expect that they will lead to increased satisfaction levels. As for user proficiency, it is expected that higher knowledge and experience with technology will allow the respondent to better navigate the application and make use of available features.

With these assumptions in mind, we phrase the hypotheses as follows:

A higher level of user proficiency will lead to higher levels of satisfaction.
and
A higher perceived accessibility of features will lead to higher levels of satisfaction.

Consequently, the following section will develop as such: we will begin with the analysis of the indicators of satisfaction, the dependent variable, and the independent variables, proficiency, and accessibility. These analyses will include correlation and reliability tests and their conclusions. Moving on, we will discuss the causal relationships between the independent variables and the dependent ones and their results, closing with the impact of control variables on *satisfaction* and whether this impact is relevant to the study.

5.3.2 Satisfaction: the dependent variable

The fourth tour of the questionnaire has the purpose of analyzing the level of satisfaction of the respondent with the features of the application. Satisfaction, in this case, is measured on the following scales, also called indicators of satisfaction: satisfaction with aliments' information, satisfaction with blockchain information, evident use of features, the effectiveness of provenance traceability, accessibility, and intuitiveness. The results to these indicators can be seen in figure 25 Using these measures, the purpose of the study is not only to report the level of satisfaction yielded by each of the elements but further analyze the Presence or absence of causal relationships between the independent variables and the indicators of satisfaction.

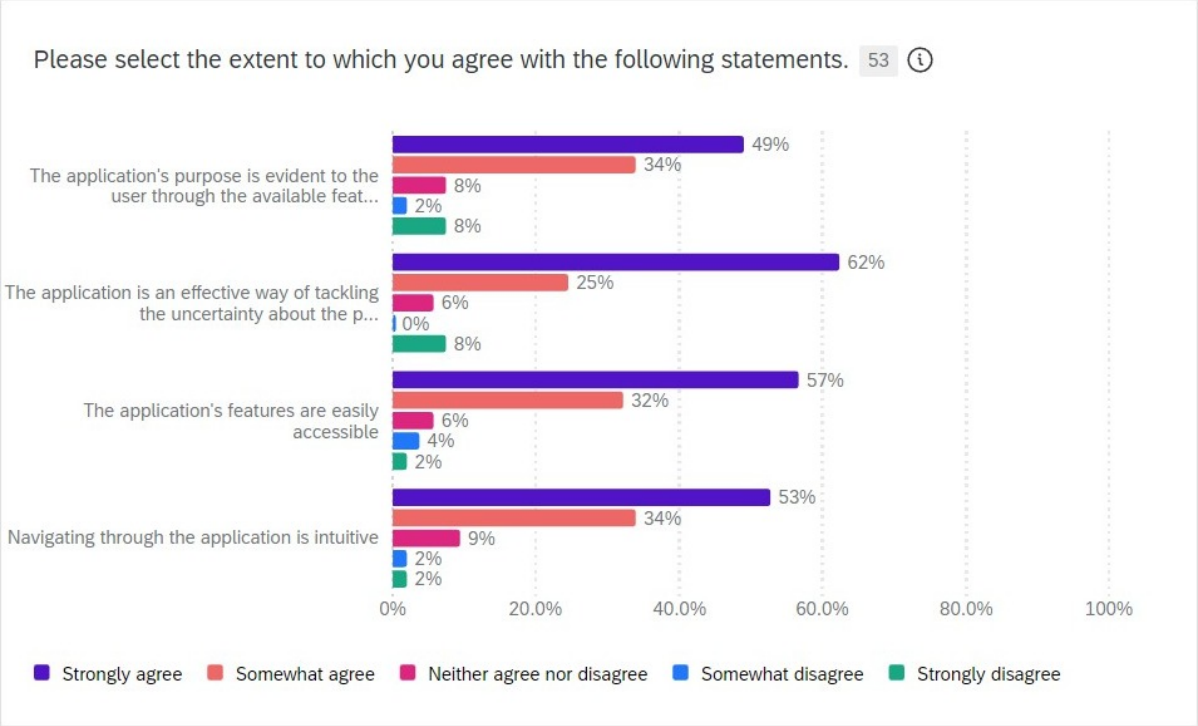


Figure 25: Survey results on the overall intuitiveness, purposefulness and satisfaction

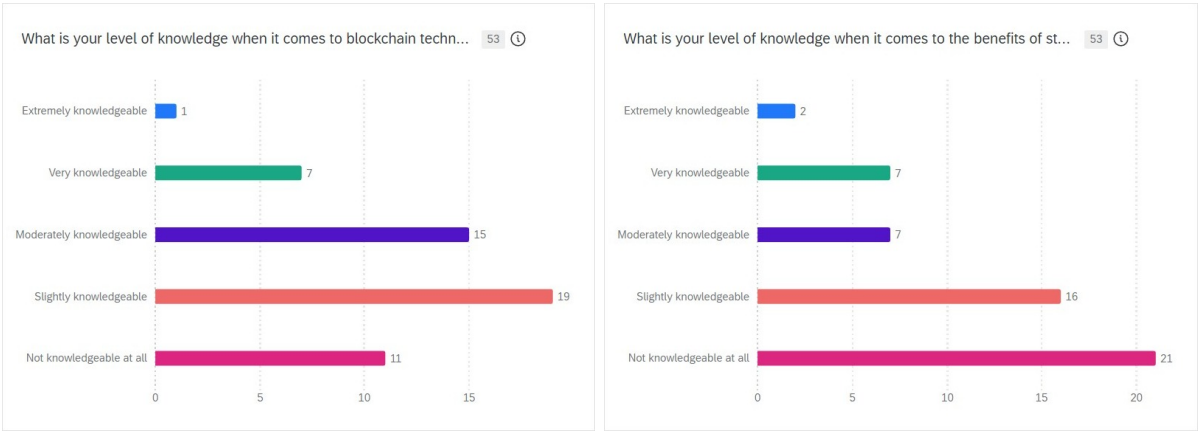
To assess the impact of the independent variables on the satisfaction indicators, we must first average the variables indicating satisfaction and thus be able to run a causality test on the relationship between the independent and dependent variables. However, the necessary preliminary step is the correlation analysis, run with the purpose of informing whether the variables in question correlate to each other and thus allow summing. If the value of the significance is lower than 0.05, then the variables are correlated and allow summing, but if the relationship between the two is not significant, summing them in into one variable will not be allowed. Interpreting the SPSS output, we identify that the only variable that does not significantly correlate with the others is the satisfaction with the aliment's information provided in the

application. Therefore, this variable will have to be excluded from the summed variable, and its causality analyzed individually. The rest are significantly correlated, and the values of the Pearson Correlation are all positive, therefore, showcasing a positive relationship between the six remaining variables.

Reliability analysis resulted in a value of Cronbach's Alpha equal to 0.886, indicating sufficient reliability to sum the variables into one. The sum of the variables was averaged for the specific number of variables involved, and the descriptive statistics indicate that the mean statistic is 4.05, within a range from 1 to 5, preliminarily indicating a high level of satisfaction.

5.3.3 Independent variables: Proficiency

The first independent variable whose effect on the satisfaction we aim to look at is the user's self-assessed proficiency in using technology in general, as seen in figure 24b, and blockchain technology in particular. The indicator questions encompassing this variable are perceived internet proficiency, blockchain knowledge, and benefits of data storage on blockchain knowledge. These three variables are measured on interval scales of 5 points, ranging from *terrible/not knowledgeable at all* to *excellent/extremely knowledgeable* and can be observed in figure 26



(a) **(b)**

Figure 26: Survey results on self-assessed proficiency
(a) Knowledge about blockchain technology (b) Knowledge of storing data on blockchain

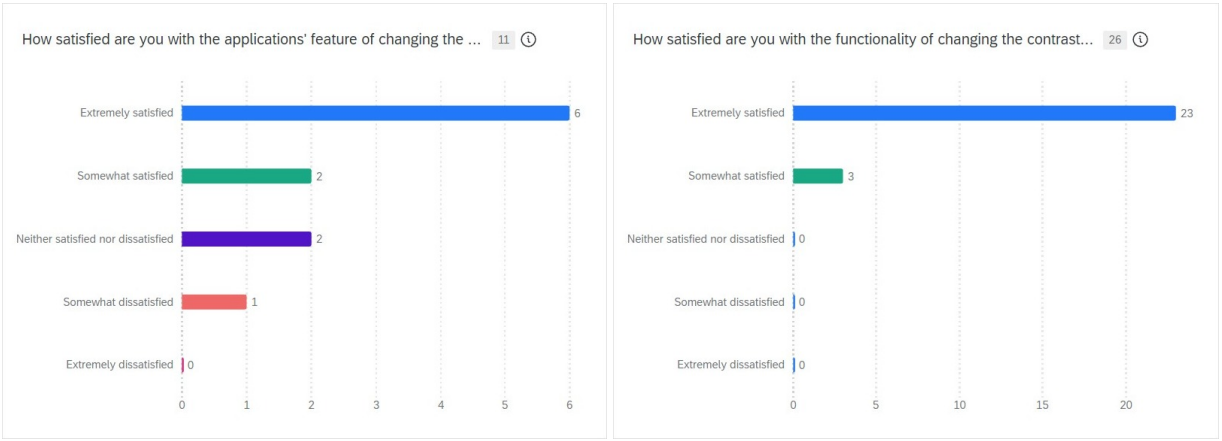
The correlation analysis indicates that the three indicators of proficiency are significantly correlated, and the result of the reliability analysis is a value of Cronbach's Alpha equal to .780. Therefore, the three variables will allow summing or averaging into one variable. The value of Cronbach's Alpha, however, also increases if the variable proficiency in using the internet is removed, thus implying a stronger relationship between the remaining two variables.

The averaged variable of proficiency has a mean of 2.906 and a standard deviation of .856.

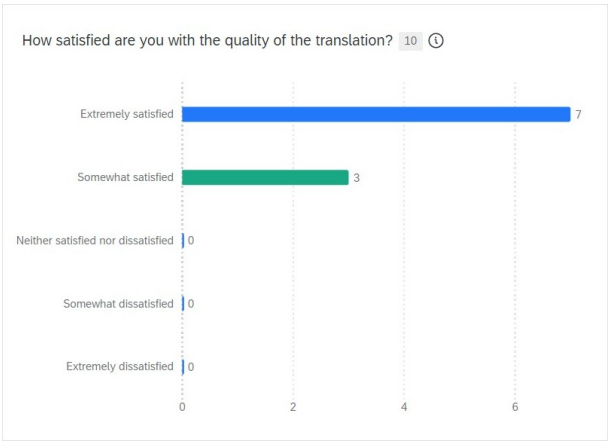
5.3.4 Independent variable: Perceived accessibility

Lastly, the second independent variable is perceived accessibility. This section is divided into accessibility features for the wide audience and accessibility features for impaired individuals who have selected their visual impairment in a preceding question. The questions inquiring about accessibility require the respondent to change the font size, contrast mode, and language. After completing this, the respondents are asked to report back with their satisfaction with the process. The responses can be seen in figure 27

Taking first the satisfaction result expressed in regards to the features available, such as changing the language, font, and contrast mode as accessibility features, we encountered a drawback. The response to this question is dependent on a positive answer to the previous questions inquiring whether the respondent has made any changes to these features. In terms of the effect on the data set, the consequence is missing



(a) **(b)**



(c)

Figure 27: Survey results on the satisfaction of accessibility features
In regards to (a) Changing the font size (b) Changing the contrast mode
(c) Quality of translation

values for all these three variables. However, for the purpose of this investigation, the missing values were replaced with a scale-mean of the other responses, thus not affecting the mean and median of the variable. The mean statistic was 4.18; the missing values were replaced by a value of 4.

After conducting a correlation analysis, the significance values are presented in table 7. In all cases, they are higher than the alpha values; thus, the variables do not correlate, and their impact on the dependent variable must be interpreted individually.

Table 7: Correlation analysis on accessibility features

	fontSize	**contrastMode**	**translation**
fontSize		sig=.947	sig=.166
contrastMode	sig=.947		sig=.221
translation	sig=.166	sig=.221	

The second indicator of accessibility is the perceived accessibility by the color blind respondents. However, in the case of two color deficiencies, the variables are constant due to the Presence of solely one answer choice. In the case of Deuteranopia, all the respondents who attempted the question chose answer choice 4 *'Somewhat distinguishable'*. In contrast, in the case of Tritanopia, the overwhelmingly chosen answer is option 5 *'Extremely distinguishable'*. In such a situation, SPSS cannot run a correlation analysis due to constant variables. Overall, these answers provide positive feedback in terms of the satisfaction experienced by visually impaired respondents.

Furthermore, we conclude that an analysis can be made on the causal relationship between proficiency and satisfaction and between the three variables of accessibility (change in font size, contrast mode, and language) and the dependent variable of satisfaction. Moreover, we will interpret the existence of a relationship between the control variables and the independent variable 'Satisfaction'.

5.3.5 Regression analysis proficiency ⟶ satisfaction

Hypothesis H_0: People with higher perceived proficiency in using technology do not feel more satisfied with the application than people with lower proficiency.

Hypothesis H_1: People with higher perceived proficiency in using technology feel more satisfied with the application than people with lower proficiency.

$$H_0: b = 0$$
$$H_1: b > 0$$

The regression is run between 2 interval-type averaged variables, and according to our hypothesis, we assume that the relationship would be significant and positive, thus implying that a high level of perceived proficiency will result in a high level of satisfaction.

However, the value of the significance is .997, far from being significant. The r^2 value is 0, thus implying the complete lack of causality between the two. The equation of the relationship is defined as:

$$satisfaction = 4.058 + 0.001 \cdot proficiency$$

It is in our interest to find out why the relationship is not as expected. To do so, we will look at the frequency statistics of the variables encompassed in the averaged proficiency variable.

While for the question regarding the proficiency of using the internet, only 18.9% have answered terrible, poor, or average, thus in the lower half, for the perceived proficiency regarding blockchain technology and the benefits of data storage on blockchain, 84.9%, and respectively 83% have given answers below or equal to the median. This is, therefore, one possible explanation for which we cannot reject the null hypothesis. It justifies that the high levels of satisfaction recorded are not caused by high levels of proficiency, but instead, users with little knowledge of blockchain technology and its benefits still find the purpose of the application evident and its features satisfactory.

5.3.6 Regression analysis accessibility ⟶ satisfaction

To analyze the relationship between the perceived accessibility of the application and satisfaction, we ran three separate regression analyses, as we had previously observed that the variables concerning accessibility could not be summed or averaged.

The first analysis is between the perceived accessibility with regards to the available font size change. Therefore, we regress the satisfaction with the font size feature on overall satisfaction. For the purpose of the analysis, we used the following hypotheses:

Hypothesis H_0: People with a higher appreciation for the font size change feature will not experience a higher level of satisfaction with the application.

Hypothesis H_1: People with a higher appreciation for the font size change feature will experience a higher level of satisfaction with the application.

$$H_0: b = 0$$
$$H_1: b > 0$$

With $r^2 = 0.33\%$, indicating that only 3.3% of the satisfaction is caused by content with accessibility features and a significance level of .193, thus too high and implying the lack of a significant relationship between the two variables, we are unable to reject the null hypothesis. The relationship can be equated to

$$satisfaction = 2.611 + 0.346 \cdot appreciationForChangingFontsizeFeature$$

In the case of contrast mode features, the significance value is .983, and the translation has a significance value of .830. The relationships are not significant, indicating that feeling content with the accessibility features does not necessarily imply satisfaction.

The equated relationships with these two variables are as follows:

$$satisfaction = 4.001 + 0.012 \cdot appreciationForContrastModeFeature$$

$$satisfaction = 0.628 + 0.730 \cdot appreciationForTranslationFeature$$

Therefore, the null hypotheses cannot be rejected for the relationship with these two variables either.

However, as discussed in a previously, the satisfaction yielded in high results implied that there is no causal relationship between the presence of accessibility features and satisfaction with the application. It is not because the satisfaction level is low but rather because satisfaction is high regardless of whether the respondent used accessibility features.

5.3.7 Control Variables

The survey consists of 3 control variables with the purpose of identifying the connection between demographics and the results concerning satisfaction. The controls used are age, last completed education, and the level of interest regarding aliments' provenance. The questions are to be answered on either ordinal or interval data scales.

5.3.7.1 Age

The first control variable to be analyzed is age. In the survey, it is defined as an ordinal scale question with seven answer choices, as presented in the appendix. For the purpose of this investigation, the ordinal scale will be turned into a nominal scale with two three categories, namely: under 18, 18-24, and 25-34 will become 'young', 35-44 and 45-54 will become 'middle aged', and 55-64 and above 65 will become 'elderly'.

After completing this modification, we had 41 respondents qualifying as young, 11 as middle-aged, and one as elderly. The mean statistic is 1.245, with a standard deviation of .477. Therefore, we conclude that most of the sample consists of young individuals, thus explaining the high internet proficiency stated.

Consequently, we analyzed using a One-way ANOVA statistical test the effect of age on the overall satisfaction presented by the respondent.

Hypothesis H_0: Age has no effect on the satisfaction experienced in regards to the application.

Hypothesis H_1: Age has an effect on the satisfaction experienced in regards to the application.

$$H_0: \mu_1 = \mu_2$$
$$H_1: \mu_1 \neq \mu_2$$

As the statistical test resulted in a value of F=.289 and significance= .750, we concluded that the test was insignificant, and thus we failed to reject the null hypothesis. Age appears to have no impact on the level of satisfaction experienced.

5.3.7.2 Educational Background

For the second control variable, last completed education, a nominal scale was used, with five potential response options, namely primary, secondary and tertiary education, followed by Masters and Ph.D. The descriptive statistics for this variable can be seen in figure **??**.

To establish whether there exists a relationship between the last completed education and satisfaction with the application, we ran a One-way ANOVA test, with the nominal variable as independent and satisfaction as the dependent variable. The following hypotheses were used to test the assumptions,

Hypothesis H_0: The last completed education does not affect the satisfaction experienced regarding the application.

Hypothesis H_1: The last completed education has an effect on the satisfaction experienced in regards to the application.

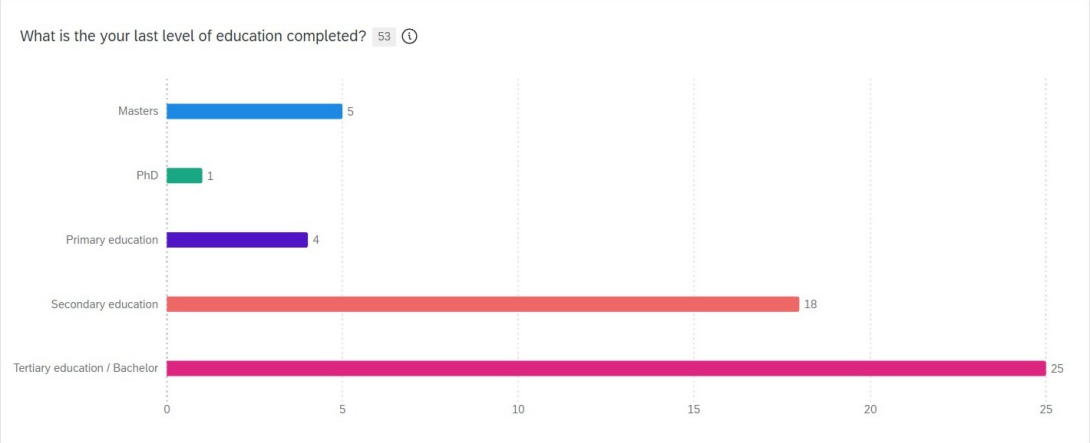


Figure 28: Last completed level of education for our respondents

$$H_0: \mu_1 = \mu_2$$
$$H_1: \mu_1 \neq \mu_2$$

The relationship is significant with sig=0.002 and F=4.972, thus indicating the Presence of a positive causal relationship between the variables. Therefore, we reject the null hypothesis and state that the last level of education completed affects satisfaction.

5.3.7.3 Aliments' provenance

The last control variable employed was the respondent's interest concerning the provenance of supermarket aliments. This variable was chosen to ponder whether those with a higher interest in provenance issues will be more likely to be satisfied with the purpose of the application and better appreciate its features. To test if this was the case, a regression analysis was run between the interval data of the control variable and the satisfaction sum variable.

Hypothesis H_0: People with a higher interest in the provenance of aliments will not experience a higher level of satisfaction with the application.

Hypothesis H_1: People with a higher interest in the provenance of aliments will experience a higher level of satisfaction with the application.

$$H_0: b = 0$$
$$H_1: b > 0$$

The analysis result was significant with a p¡0.001 and $r^2 = .281$, indicating that 28.1% of satisfaction can be explained by a high interest in the aliment's provenance. The relationship can be defined as:

$$satisfaction = 2.742 + 0.408 \cdot provenanceInterest$$

Thus, we reject the null hypothesis and state that a higher interest towards provenance of aliments will lead to higher satisfaction levels with the application.

5.4 Main findings

According to the analysis we set out to complete, the findings of this primary data analysis are both expected and unexpected in different ways. To begin with, the two initially set out hypotheses could not be confirmed, thus implying that proficiency and accessibility were not the factors that yielded satisfaction in the respondents. Concerning satisfaction, the statistics are highly positive, indicating a high level of content from the majority of the participants, with an average mean of 4.059. Moreover, while there has been no relationship identified between the independent variables and the dependent ones, we can state the following: proficiency has been recorded to be low, especially in questions concerning blockchain technology knowledge; this, however, not being a reason for the participant to be dissatisfied with the

application. This finding confirms the outcome we were looking to achieve: making the application available and valuable for users of all proficiency levels. Secondly, while we cannot state that either of the independent variables presents a significant relationship to the dependent, we have found that the last education completed and the interest shown towards aliments' provenance positively affect satisfaction. Thus, we conclude that individuals with education levels beyond secondary education generally have the highest satisfaction levels recorded and that one's interest will also result in increased content with the application's purpose. The respondents who have selected to be suffering from CVD have highly rated the color deficiency features that allow deficiencies to be overcome when using the application.

To summarize all the findings, we state that the application seems to have achieved its purpose of being as accessible and available to as many individuals as possible, and its use is not restricted by proficiency, age, or visual imparities.

5.5 Threats to validity

As validity is the most relevant characteristic of a statistical study, we present the threats that might have, in the process, biased results. Firstly, we begin by looking at the sample used for the survey. As seen in the previous analysis, the sample is skewed regarding age, indicating a much higher percentage of young people compared to middle-aged and elderly. This bias is caused by the distribution channels of the survey, as well as by the proclivity of young people to be more in contact with technology and be interested in new findings. Secondly, the respondent's need for accessibility issues could have been more strongly enforced by additional demographic questions and inquiries referring to eyesight quality. This would have provided more information regarding the conditions that motivate a user to take advantage of accessibility features available.

6 Discussion

In this section, we aim to present other findings that have resulted from the distribution of the survey. Our results show that if a supermarket was to introduce a decentralized application able to trace the provenance of their inventory, the likeliness of our respondents to use such dApp is 81% as seen in figure 29

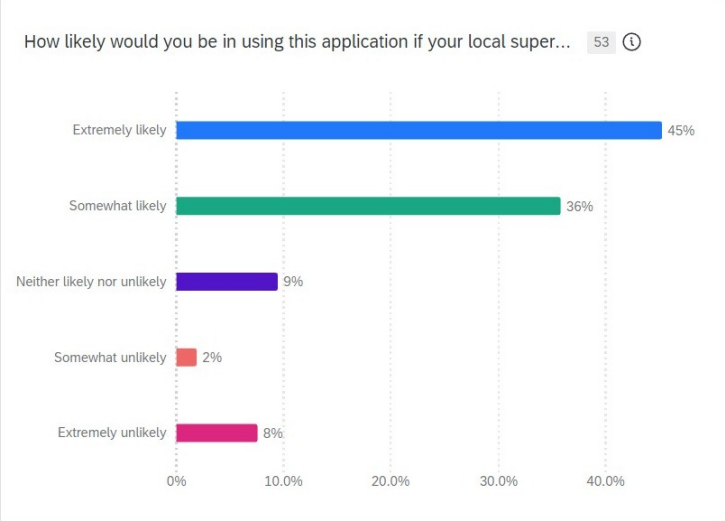


Figure 29: Likeliness of respondents for using a supermarket dApp to check the provenance of groceries

Another relevant finding refers to the products respondents consider worth knowing about their provenance. This information is shown in figure 30. Supermarkets or other entities can easily use it to prioritize their implementation to improve their products' credibility.

Other findings include examples of features our respondents would like to present in the application. Information regarding nutrition labels, expiration dates, ingredients, and carbon footprint seems to be on the top of the priority list regarding users' wants.

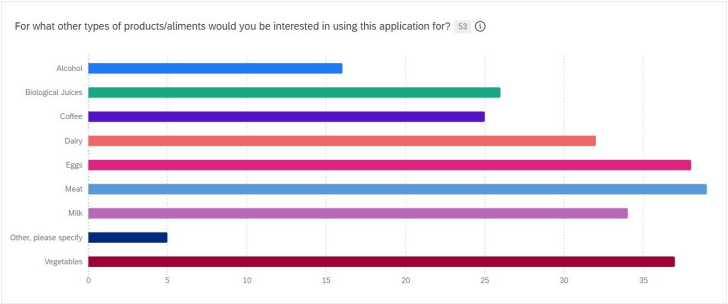


Figure 30: Public interest for products in need of provenance tracking

6.1 Future Plans

With the completion of this bachelor project, we can now give some recommandations on what could be done to further extend and improve the application, such as the following

- **Connecting to a blockchain**

  The initial intent of this bachelor's project was to create a decentralized application. Although several applications have been made to TradeLens, VeChain, TrustChain, and Ambrosus, no responses have been received. Therefore, we had to change the direction and transform it into a Proof-of-Concept (PoC). Having said this, the application has been implemented in such a way that refactoring it at a later point to use smart contracts instead of Firestore requires the changing of only one function.

- **Adding color scheme for achromatopsia user**

  In terms of accommodating users with color deficiencies, we have only thought of dichromats and anomalous trichromats as they represent a majority, compared to achromatopsia with only 0.001% cases worldwide as discussed in 2.1.5.1. We have received feedback from survey respondents of the survey saying that their experience with our application could have been improved by using a colour scheme in black and white contrasts. A possible reason for this might be that color blind people distinguish shades better than non-color blind people.

7 Conclusion

The main goal of this project was to develop an application able to trace supermarket products at any point throughout the supply chain. The application had to be accessible to a broad audience regardless of age, language spoken, device owned, or disabilities. We have followed two methodologies throughout the implementation process, namely, *Design Thinking* and *Atomic Design*. In order to adapt the colour scheme used by our interface for colour-blind people, we have used the *LMS Daltonization* algorithm. The internationalization of our application has been done both automatically and manually. The *hard-content*, which consists of labels and descriptions that do not change their state at any point in time, were manually translated. Meanwhile, *dynamic-content* has been translated with the use of Google's Cloud Translation API.

Following the implementation process, a survey was conducted *(N = 53)* consisting of questions related to demographics, accessibility, and overall satisfaction with the application. The survey intended to help answer the research questions encompassed in the thesis, namely " *To what extent does a high level of accessibility provided by the application and a high level of user proficiency lead to increased satisfaction levels?*". A statistical analysis has been carried out, which shows that neither self-assessed proficiency nor the perceived level of accessibility were factors contributing to the respondents' overall satisfaction. Moreover, the last level of education completed and interest shown towards knowing more about the product's provenance positively impacts satisfaction. It justifies that the high levels of satisfaction recorded are not caused by high levels of proficiency, but instead, users with little knowledge of blockchain technology and its benefits still find the purpose of the application evident and its features satisfactory. The color-blind respondents *(N = 6)* have rated highly the colour-blind mode of the application used to overcome their imparity.

The secondary research question refers to the most suited framework to build an application with such a use case. Following the statistical analysis, we conclude that Angular is the best choice due to its extensive developer tooling, maintainability, and upgradability abilities after the bachelor project is done.

Some other exciting findings deducted from the survey show that 81% of our respondents would use a supermarket dApp to track the provenance of their groceries. Our respondents also show high interest in their groceries' nutrition labels, ingredients, and carbon footprint.

Overall, we can state that the application fulfilled its purpose of being accessible to a broad audience; however, more research and innovation into accessibility are needed to improve the mass adoption of dApps further.

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A LMS Daltonization Algorithm

```
# LMS Daltonization algorithm
# Based on the algorithm in
# https://online-journals.org/index.php/i-jim/article/view/8160/5068

import numpy as np
from PIL import Image
import matplotlib.pyplot as plt

lmsColorSpace = np.array([[17.8824, 43.5161, 4.11935],
                          [3.45565, 27.1554, 3.86714],
                          [0.0299566, 0.184309, 1.46709]])

rgbColorSpace = np.array([[0.0809444479, -0.130504409, 0.116721066],
                          [0.113614708, -0.0102485335, 0.0540193266],
                          [-0.000365296938, -0.00412161469, 0.693511405]])

simulationProtonopia = np.array([[0, 2.02344, -2.52581],
                                 [0, 1, 0],
                                 [0, 0, 1]])

simulationDuteranopia = np.array([[1, 0, 0],
                                  [0.49421, 0, 1.24827],
                                  [0, 0, 1]])

simulationTritanopia = np.array([[1, 0, 0],
                                 [0, 1, 0],
                                 [-0.395913, 0.801109, 0]])

errorMatrixProtonopia = np.array([[0, 0, 0],
                                  [0.7, 1, 0],
                                  [0.7, 0, 1]])

errorMatrixDuteranopia = np.array([[1, 0.7, 0],
                                   [0, 0, 0],
                                   [0, 0.7, 1]])

errorMatrixTritanopia = np.array([[1, 0, 0.7],
                                  [0, 1, 0.7],
                                  [0, 0, 0]])


def rgb_to_lms(rgbColor):
    return np.dot(lmsColorSpace, rgbColor)


if __name__ == '__main__':
    # Defining the color to be corrected

    ionicPrimary = np.array([[56],
                             [128],
                             [255]])

    ionicSecondary = np.array([[61],
                               [194],
                               [255]])

    ionicTertiary = np.array([[82],
                              [96],
                              [255]])

    ionicSuccess = np.array([[45],
```

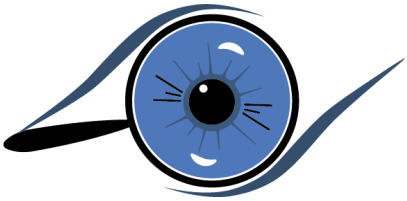
```
                          [211],
                          [111]])

ionicWarning = np.array([[255],
                         [196],
                         [9]])

ionicDanger = np.array([[235],
                        [68],
                        [90]])

colorAboutToBeConverted = ionicDanger

# Transforming the colors to LMS mode
# which is the visible spectrum
hslColor = rgb_to_lms(colorAboutToBeConverted)

# Simulating the hsl color for each color deficiency
simulatedProtonopia = np.dot(simulationProtonopia, hslColor)
simulatedDuteranopia = np.dot(simulationDuteranopia, hslColor)
simulatedTritanopia = np.dot(simulationTritanopia, hslColor)

# Transforming back the simulated colors into RGB color space
rgbSimulatedProtonopia = np.clip(np.dot(rgbColorSpace, simulatedProtonopia),
                                 0, 255).astype(int)
rgbSimulatedDuteranopia = np.clip(np.dot(rgbColorSpace, simulatedDuteranopia),
                                  0, 255).astype(int)
rgbSimulatedTritanopia = np.clip(np.dot(rgbColorSpace, simulatedTritanopia),
                                 0, 255).astype(int)

# Calculating the difference between the original and simulated images
diffRgbProtonopia = np.subtract(colorAboutToBeConverted, rgbSimulatedProtonopia)
diffRgbDuteranopia = np.subtract(colorAboutToBeConverted,
    rgbSimulatedDuteranopia)
diffRgbTritanopia = np.subtract(colorAboutToBeConverted, rgbSimulatedTritanopia)

# Shift colors towards the visible spectrum by multiplying with the error
    matrices
shiftedRgbProtonopia = np.dot(errorMatrixProtonopia, diffRgbProtonopia)
shiftedRgbDuteranopia = np.dot(errorMatrixDuteranopia, diffRgbDuteranopia)
shiftedRgbTritanopia = np.dot(errorMatrixTritanopia, diffRgbTritanopia)

# Add the shifted differences with the original RGB colour.
# The result is the original RGB color daltonized
finalShiftedColorProtonopia = np.clip(np.add(colorAboutToBeConverted,
                                             shiftedRgbProtonopia), 0, 255) \
                                             .astype(int)
finalShiftedColorDuteranopia = np.clip(np.add(colorAboutToBeConverted,
                                              shiftedRgbDuteranopia), 0, 255)\
                                             .astype(int)
finalShiftedColorTritanopia = np.clip(np.add(colorAboutToBeConverted,
                                             shiftedRgbTritanopia), 0, 255)\
                                             .astype(int)

# Creating the 2x2 grid for the plots
f, axarr = plt.subplots(2, 2)

# Converting the final arrays into bytes
colorToBeConvertedCopy = bytes(np.transpose(colorAboutToBeConverted)
                               .flatten().tolist())
protonopiaColorImage = bytes(np.transpose(finalShiftedColorProtonopia)
                             .flatten().tolist())
duteranopiaColorImage = bytes(np.transpose(finalShiftedColorDuteranopia)
```

```
                                .flatten().tolist())
    tritanopiaColorImage = bytes(np.transpose(finalShiftedColorTritanopia)
                                .flatten().tolist())

    # Converting bytes into images
    originalColorImage = Image.frombytes(mode='RGB',
                                         size=(1, 1), data=colorToBeConvertedCopy)
    simulatedProtonopiaImage = Image.frombytes(mode='RGB',
                                               size=(1, 1), data=
                                                   protonopiaColorImage)
    simulatedDuteranopiaImage = Image.frombytes(mode='RGB',
                                                size=(1, 1), data=
                                                    duteranopiaColorImage)
    simulatedTritanopiaImage = Image.frombytes(mode='RGB',
                                               size=(1, 1), data=
                                                   tritanopiaColorImage)

    axarr[0, 0].imshow(originalColorImage)
    axarr[0, 1].imshow(simulatedProtonopiaImage)
    axarr[1, 0].imshow(simulatedDuteranopiaImage)
    axarr[1, 1].imshow(simulatedTritanopiaImage)

    plt.savefig("figure.png")
    plt.show()
```

B Survey Questions

Question Tour Block 1

TracingLens - A new decentralized application (dApp) to help trace your supermarket aliments from farm to table, through each step of the logistical process.



This survey has been made available for the purposes of testing and gathering feedback on the **TracingLens** application, developed as part of a Bachelor project at the University of Groningen, in collaboration with the University of Malta.

The responses received from this survey will be anonymised with no possible way of identifying the respondents' IP address, location data or contact info.

The survey is expected to be completed in about 6 minutes and can be done both on web and mobile.

By answering this survey, you do not only help the scientific community, but also the developers' community in making websites more accessible so that people with disabilities can make use of them equally.

What is your age?

- ○ Under 18
- ○ 18-24
- ○ 25-34
- ○ 35-44
- ○ 45-54
- ○ 55-64
- ○ 65 and above

What is the your last level of education completed?

- ○ Primary education
- ○ Secondary education
- ○ Tertiary education / Bachelor
- ○ Masters
- ○ PhD

Please rate your proficiency using the internet and/or technology

- ○ Terrible
- ○ Poor
- ○ Average
- ○ Good
- ○ Excellent

What is your level of knowledge when it comes to blockchain technology?

- ○ Not knowledgeable at all
- ○ Slightly knowledgeable
- ○ Moderately knowledgeable
- ○ Very knowledgeable
- ○ Extremely knowledgeable

What is your level of knowledge when it comes to the benefits of storing data on the blockchain?

- ○ Not knowledgeable at all
- ○ Slightly knowledgeable
- ○ Moderately knowledgeable
- ○ Very knowledgeable
- ○ Extremely knowledgeable

How would you rate your interest in tracing the provenance of supermarket aliments?

- ○ Not at all important
- ○ Slightly important
- ○ Moderately important
- ○ Very important
- ○ Extremely important

Question Tour Block 2

In this second part of the survey, you will answer questions regarding accessibility .

Which color vision deficiency do you suffer from?

- ○ Protanopia (Red-Green color blindness)
- ○ Deuteranopia (Red-Green color blindness)
- ○ Triteranopia (Blue-Yellow color blindness)
- ○ Achromatopsia (Total color blindness)
- ○ None

How would you rate your level of vision?

- ○ Very poor vision - using a computer is impossible without assistive technology (e.g. screen reader)
- ○ Poor vision - notably impacts your ability to use a computer
- ○ Moderate vision - using a computer is possible using correction (e.g. glasses, contact lenses)
- ○ Adequate vision

Which of the following assistive technology do you frequently use?

- [ ] Screen Reader
- [ ] Screen magnification software or system/application settings
- [ ] Browser zoom controls (pinch in/out zoom)
- [ ] High Contrast mode or settings
- [ ] Tools that highlight text as it is read
- [ ] I do not use any of the above technologies
- [ ] _____ Other, please mention which one

What screen reader is your most frequently used one?

- ○ I do not use a screen reader
- ○ JAWS
- ○ NVDA
- ○ VoiceOver
- ○ Narrator
- ○ _____ Other, please specify which one

What type of contrast mode do you frequently use?

- ○ **Light text on a dark background**
- ○ **Dark text on a light background**
- ○ I do not know
- ○ I do not have a preference

What type of text size do you frequently use?

- ○ Default
- ○ Increased Size
- ○ Decreased Size
- ○ I do not know

Question Tour Block 3

Before we move on to the next part of the survey, please open a new page containing the TracingLens application, on the same device you are taking the questionnaire.

If you want to open it on a new device, other than the current one, please input the following link into the address bar *https://tracinglens.web.app/settings*

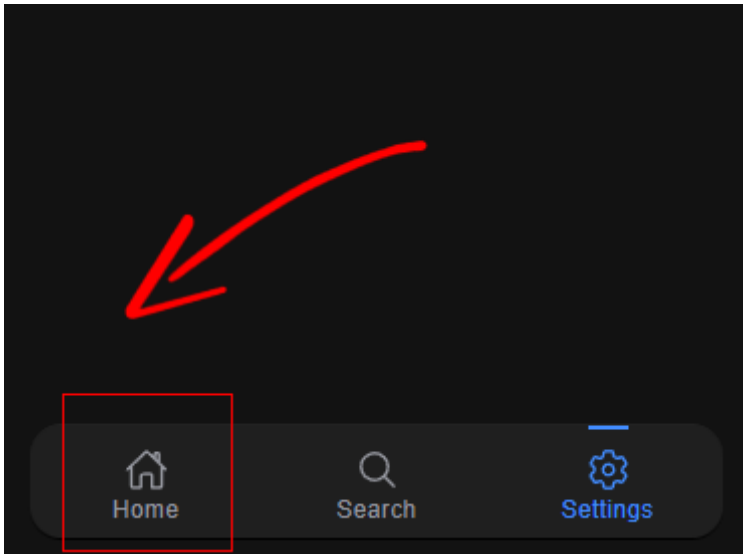
or

Scan the following QR code which will redirect you to the settings page of the application.

Now, please make the necessary adjustments when it comes to the language, font size, contrast and color blind mode of the application

- ○ I have made the necessary adjustments to the application in terms of language, font size, contrast and color blind mode according to my needs.

Please navigate to the homepage by clicking the first tab button at the bottom of the screen.



Take a moment to observe the content and graphs presented, then proceed to the next section.

Now, please navigate to the search page, by clicking on the middle tab, situated at the bottom of the screen.

To look through the lifecycles of a product/aliment, you have three available ways of achieving it, as such:

1. Input manually into the search box **OnXfdzNqv1NbXs6aqIgv**, representing the product ID.
2. Click on the "Scan QR Code" button, enable the camera then scan the following QR code.

3. By scanning the following QR code in your ordinary QR scanner application

As a last resort, by clicking here, a new page will be opened, achieving the same end result as any of the above-mentioned methods.

- ○ I have successfully completed one of the steps above

Questions Tour Block 4

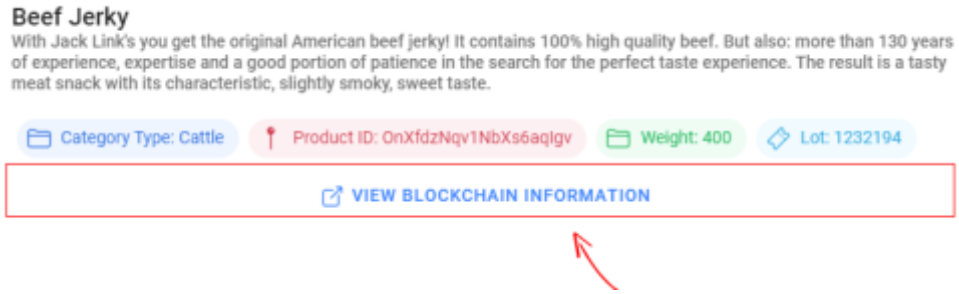
Have a brief look through the page then answer the following questions:

How satisfied are you with regards to the amount of information provided on the aliments' page?

- ○ Extremely dissatisfied
- ○ Somewhat dissatisfied

- ○ Neither satisfied nor dissatisfied
- ○ Somewhat satisfied
- ○ Extremely satisfied

How satisfied are you with regards to the authenticity of the data after clicking on the "View Blockchain Information"?



- ○ Extremely dissatisfied
- ○ Somewhat dissatisfied
- ○ Neither satisfied nor dissatisfied
- ○ Somewhat satisfied
- ○ Extremely satisfied

Please select the extent to which you agree with the following statements.

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
The application's purpose is evident to the user through the available features	○	○	○	○	○
The application is an effective way of tackling the uncertainty about the provenance of a product/aliment	○	○	○	○	○
The application's features are easily accessible	○	○	○	○	○

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
Navigating through the application is intuitive	○	○	○	○	○

Question Tour Block 5

What Operating System have you used to check the application?

- ○ Windows
- ○ macOS
- ○ iOS
- ○ Android
- ○ Linux
- ○ I do not know
- ○ [ ] Other, please specify

What browser have you used to check the application?

- ○ Chrome
- ○ Firefox
- ○ Opera
- ○ Safari
- ○ Microsoft Edge
- ○ I do not know
- ○ [ ] Other, please specify

As a user suffering from *Protanopia*, how distinguishable is the colour scheme used throughout the application?

- ○ Extremely indistinguishable
- ○ Somewhat indistinguishable
- ○ Neither distinguishable nor indistinguishable
- ○ Somewhat distinguishable
- ○ Extremely distinguishable

As a user suffering from *Deuteranopia*, how distinguishable is the colour scheme used throughout the application?

- ○ Extremely indistinguishable
- ○ Somewhat indistinguishable
- ○ Neither distinguishable nor indistinguishable
- ○ Somewhat distinguishable
- ○ Extremely distinguishable

As a user suffering from *Triteranopia*, how distinguishable is the colour scheme used throughout the application?

- ○ Extremely indistinguishable
- ○ Somewhat indistinguishable
- ○ Neither distinguishable nor indistinguishable
- ○ Somewhat distinguishable
- ○ Extremely distinguishable

Have you at any point, changed the font size of the application?

- ○ No
- ○ Yes

Have you used the application in another language other than English?

- ○ No
- ○ Yes

Have you at any point, used the application in high contrast mode (dark mode)?

- ○ No
- ○ Yes

How satisfied are you with the applications' feature of changing the font size?

- ○ Extremely dissatisfied
- ○ Somewhat dissatisfied
- ○ Neither satisfied nor dissatisfied
- ○ Somewhat satisfied
- ○ Extremely satisfied

How satisfied are you with the functionality of changing the contrast mode (dark mode)?

- ○ Extremely dissatisfied
- ○ Somewhat dissatisfied
- ○ Neither satisfied nor dissatisfied
- ○ Somewhat satisfied
- ○ Extremely satisfied

In what language have you used the application?

[ ]

How satisfied are you with the quality of the translation?

- ○ Extremely dissatisfied
- ○ Somewhat dissatisfied
- ○ Neither satisfied nor dissatisfied
- ○ Somewhat satisfied
- ○ Extremely satisfied

How likely would you be in using this application again?

- ○ Extremely unlikely
- ○ Somewhat unlikely
- ○ Neither likely nor unlikely
- ○ Somewhat likely

- ○ Extremely likely

How likely would you be in using this application if your local supermarket were to introduce it?

- ○ Extremely unlikely
- ○ Somewhat unlikely
- ○ Neither likely nor unlikely
- ○ Somewhat likely
- ○ Extremely likely

For what other types of products/aliments would you be interested in using this application for?

- ☐ Meat
- ☐ Milk
- ☐ Dairy
- ☐ Coffee
- ☐ Vegetables
- ☐ Eggs
- ☐ Alcohol
- ☐ Biological Juices
- ☐ [ ] Other, please specify

What kind of feature would you like to be implemented in this application?

Questions Tour Block 6

Do you have any other ideas on improving the application?

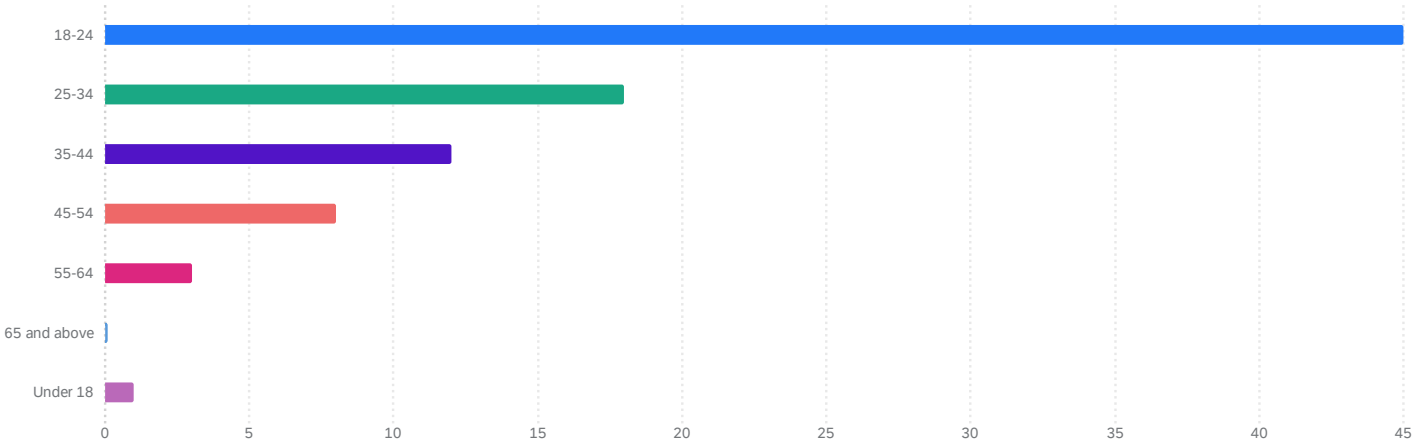
Any feedback is much appreciated and will be taken into consideration!

Powered by Qualtrics

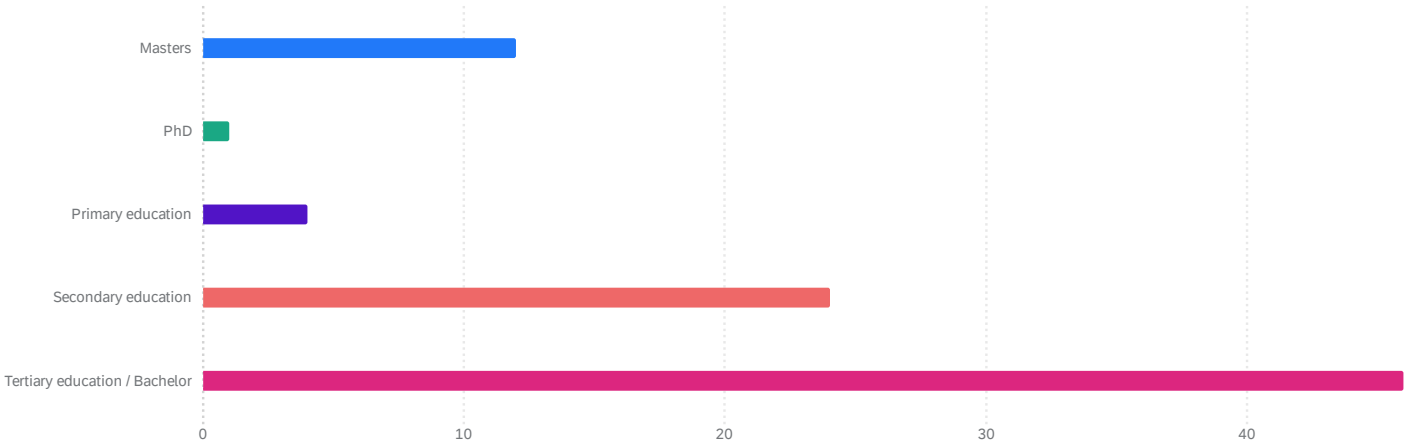
C Survey Answers

...sponses: 116

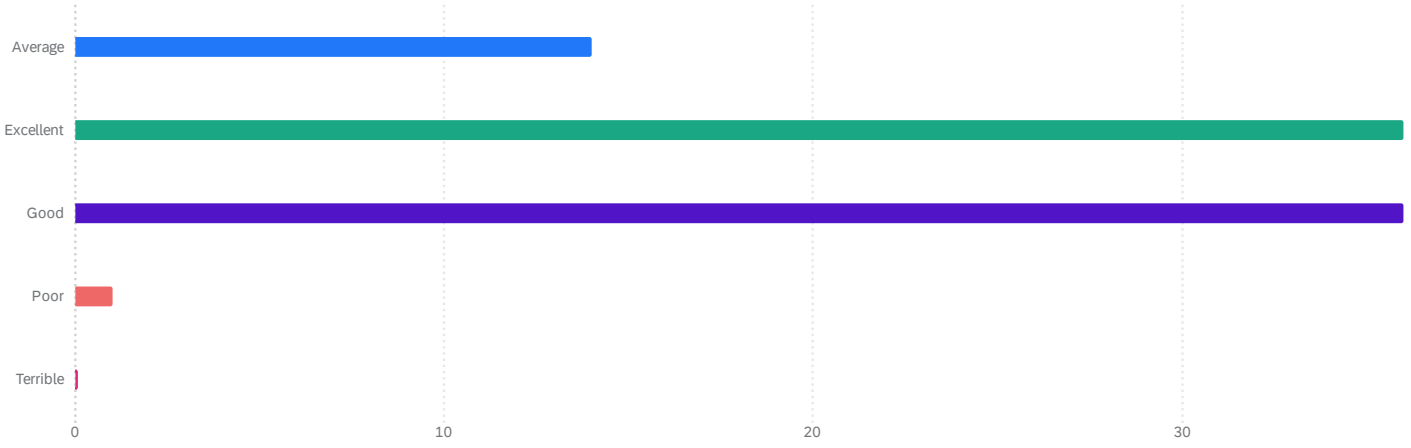
What is your age?



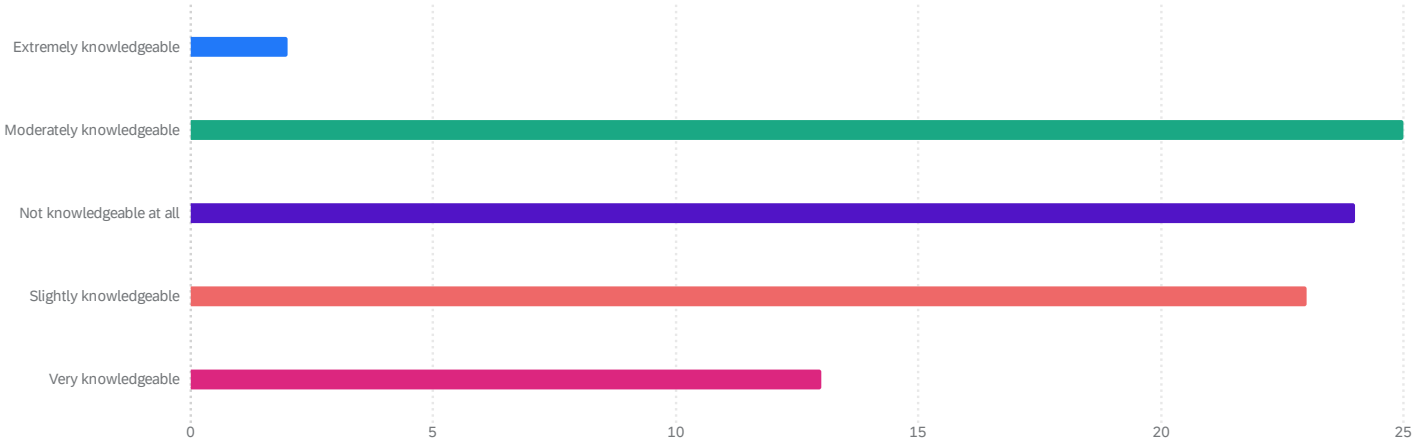
What is the your last level of education completed?



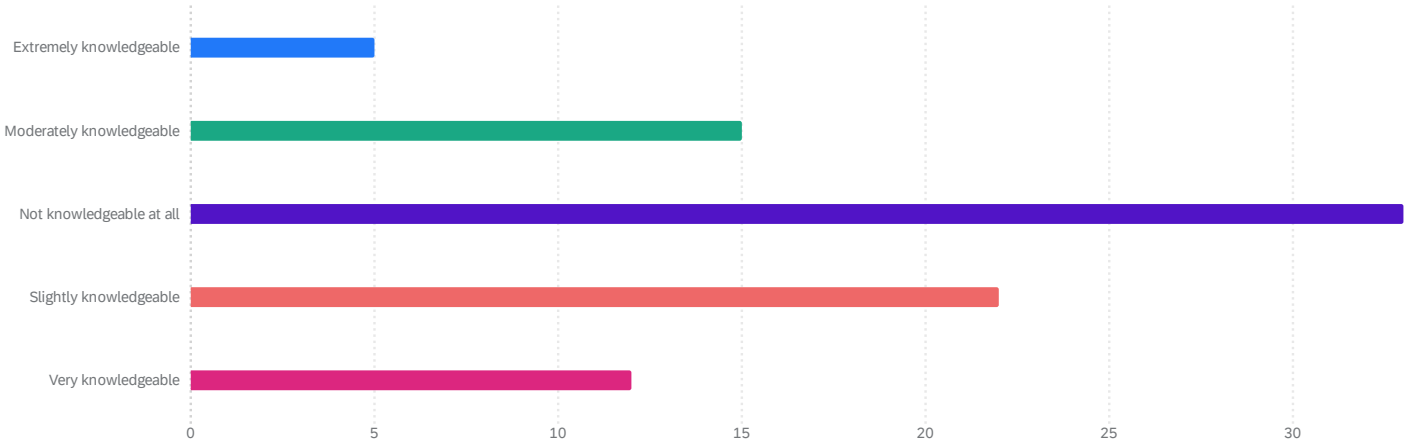
Please rate your proficiency using the internet and/or technology



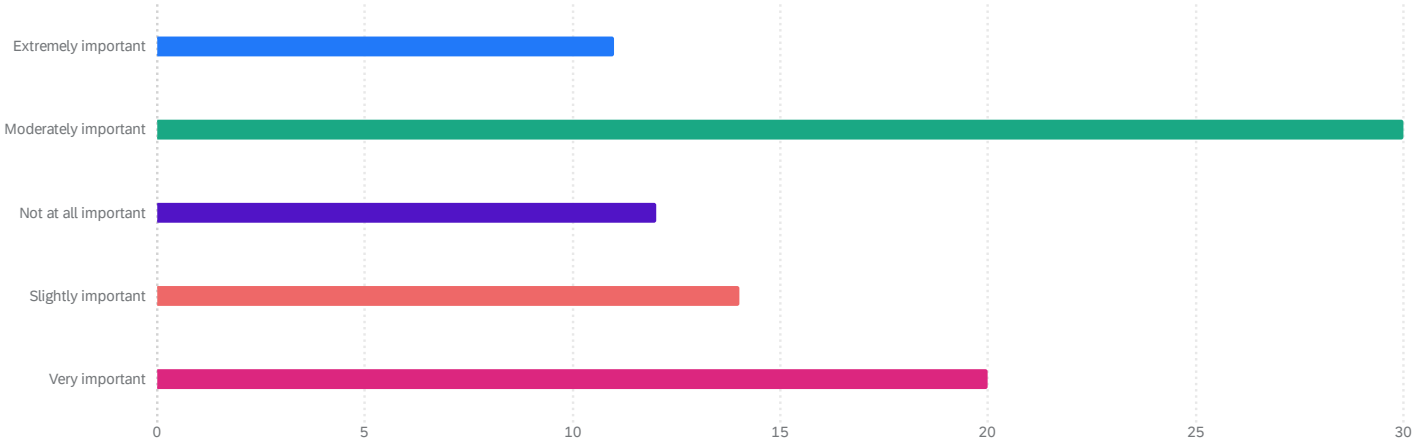
What is your level of knowledge when it comes to blockchain technology?



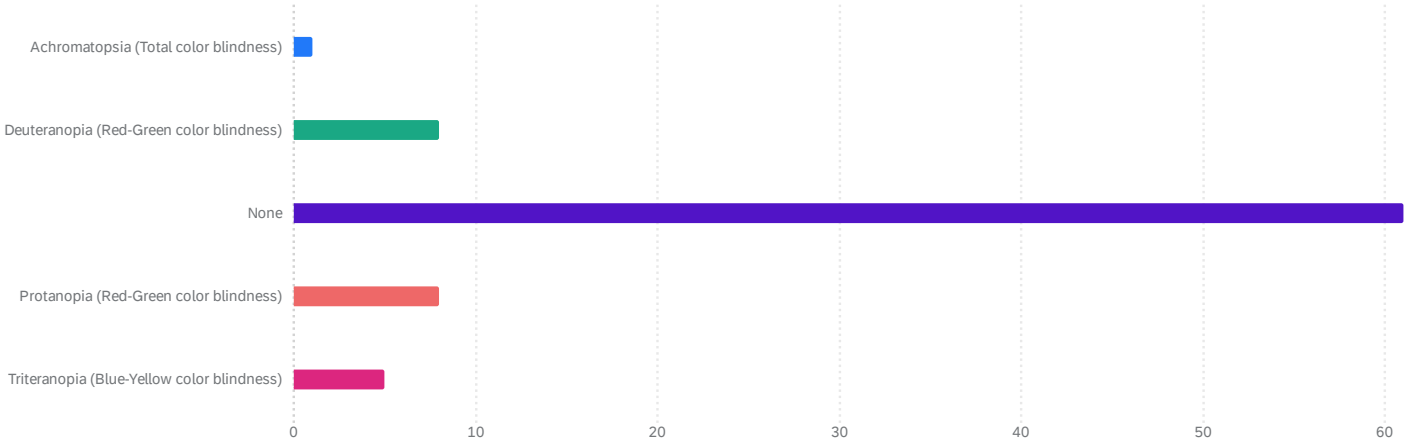
What is your level of knowledge when it comes to the benefits of storing data on the blockchain?



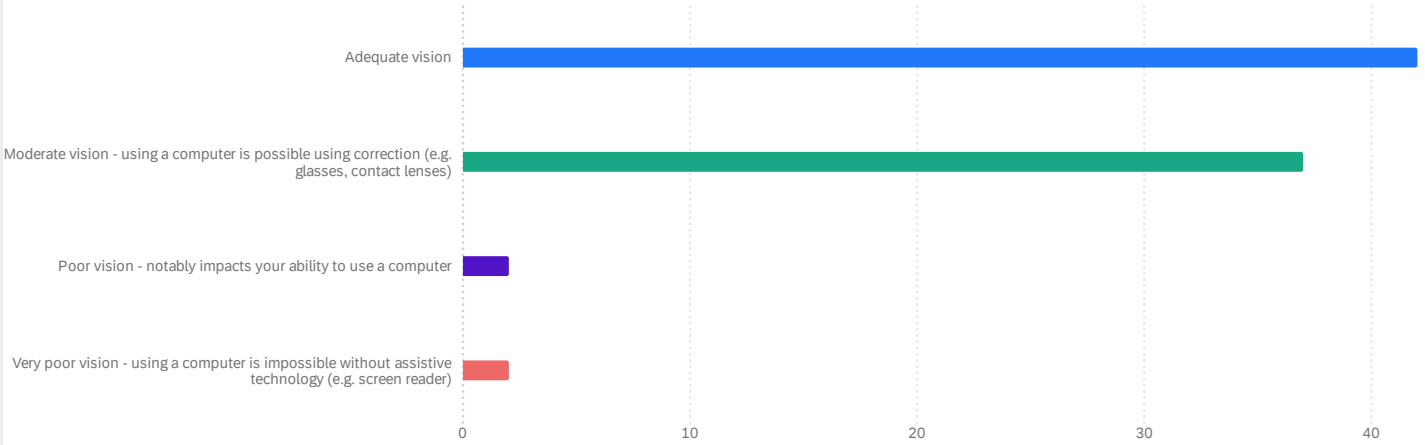
How would you rate your interest in tracing the provenance of supermarket aliments?



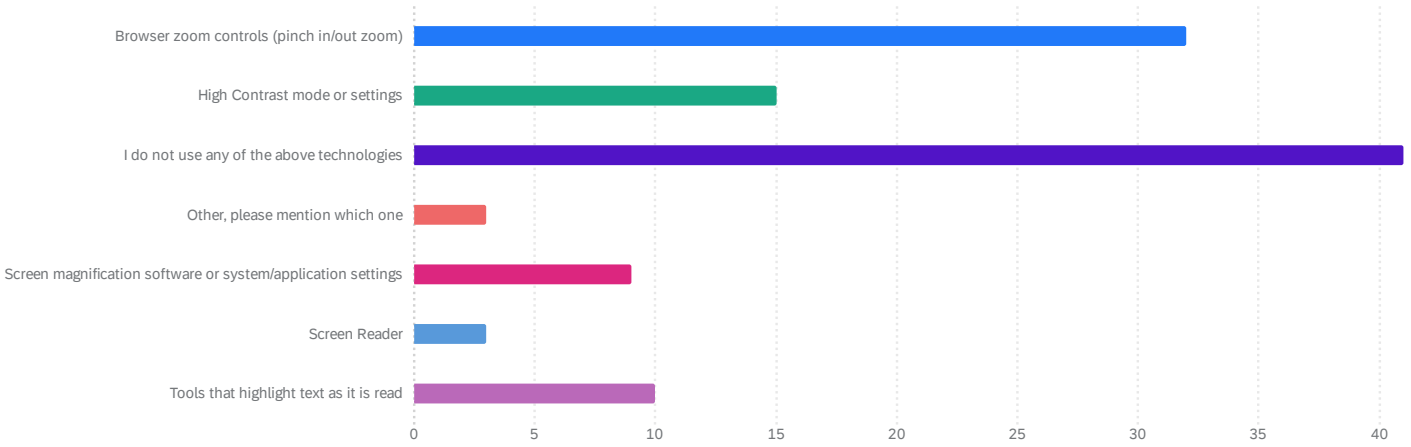
Which color vision deficiency do you suffer from?



How would you rate your level of vision?



Which of the following assistive technology do you frequently use?



Which of the following assistive technology do you frequently use?: Other, please mention which one

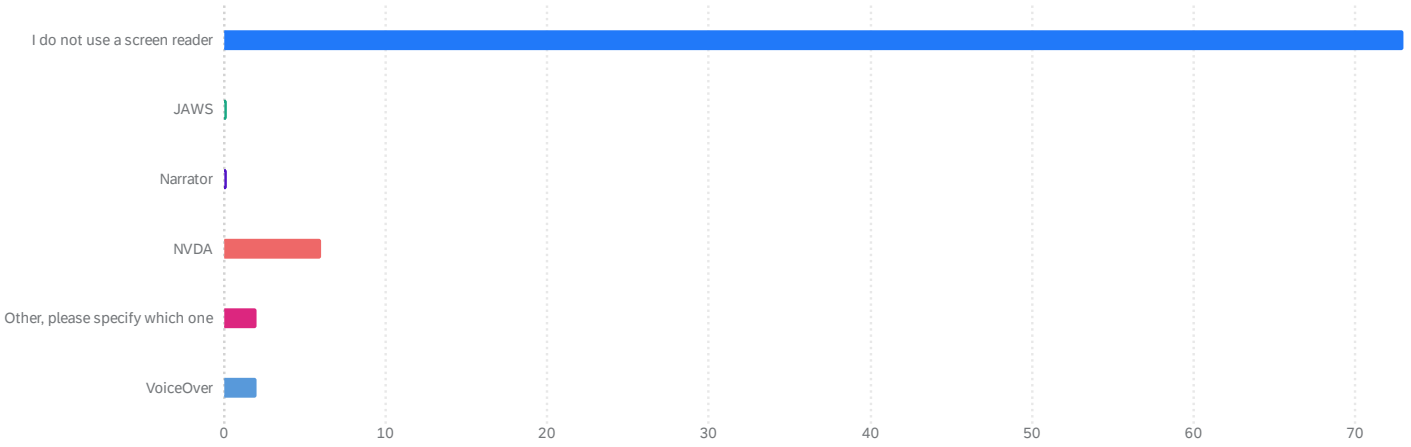
blue filter if that counts

Just mentioning that I'm sometimes using browser zoom controls because of a high resolution

Daltonizer

No more results to show

What screen reader is your most frequently used one?



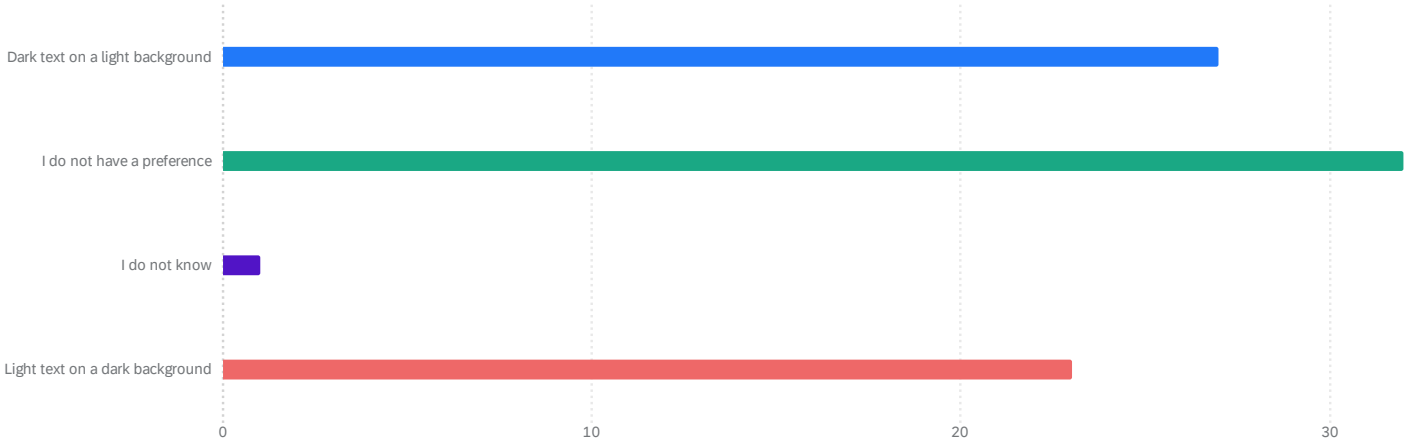
What screen reader is your most frequently used one?: Other, please specify which one

Chromaglass

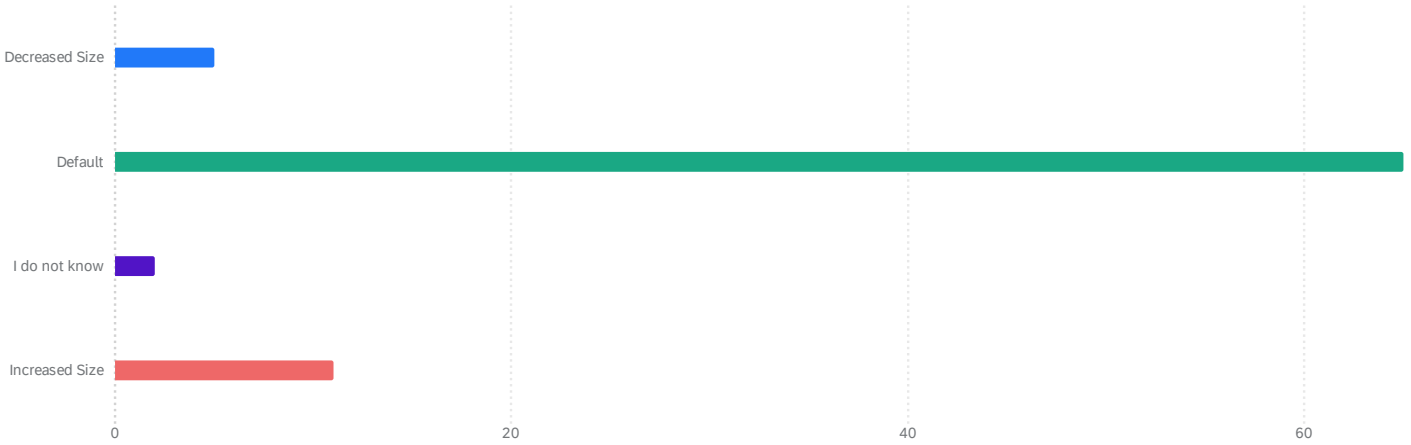
Read and write

No more results to show

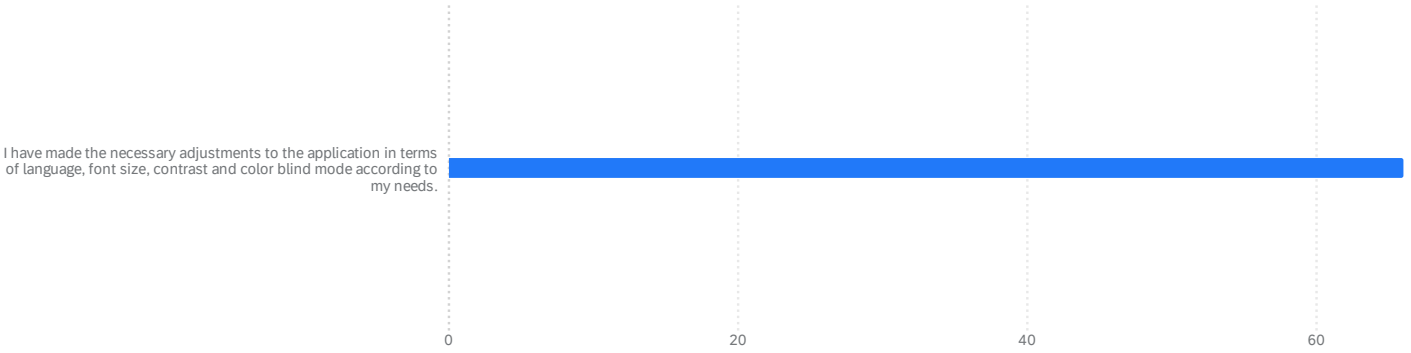
What type of contrast mode do you frequently use?



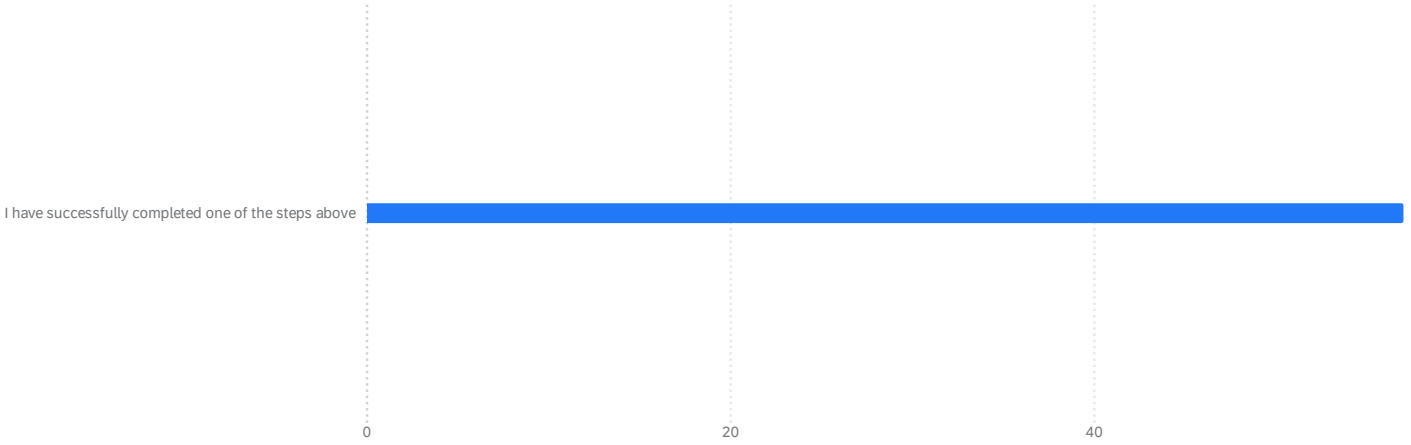
What type of text size do you frequently use?



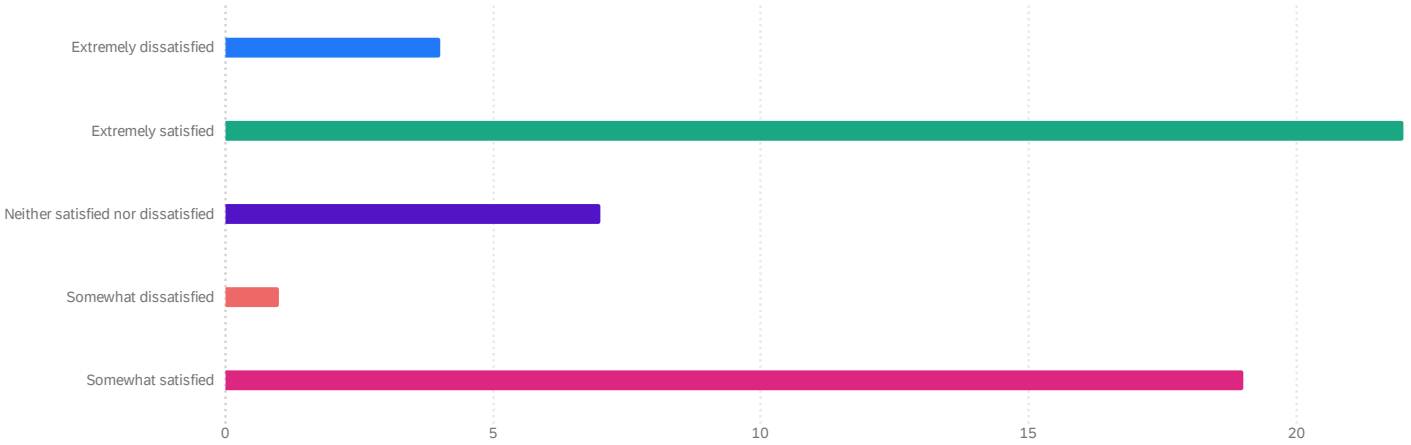
Before we move on to the next part of the survey, please open a new page containing the TracingLens application, on the same device you are taking the questionnaire. If you want to open it on a new device, other than the current one, please input the following link into the address bar https://tracinglens.web.app/settings or Scan the following QR code which will redirect you to the settings page of the application. Now, please make the necessary adjustments when it comes to the language, font size, contrast and color blind mode of the application



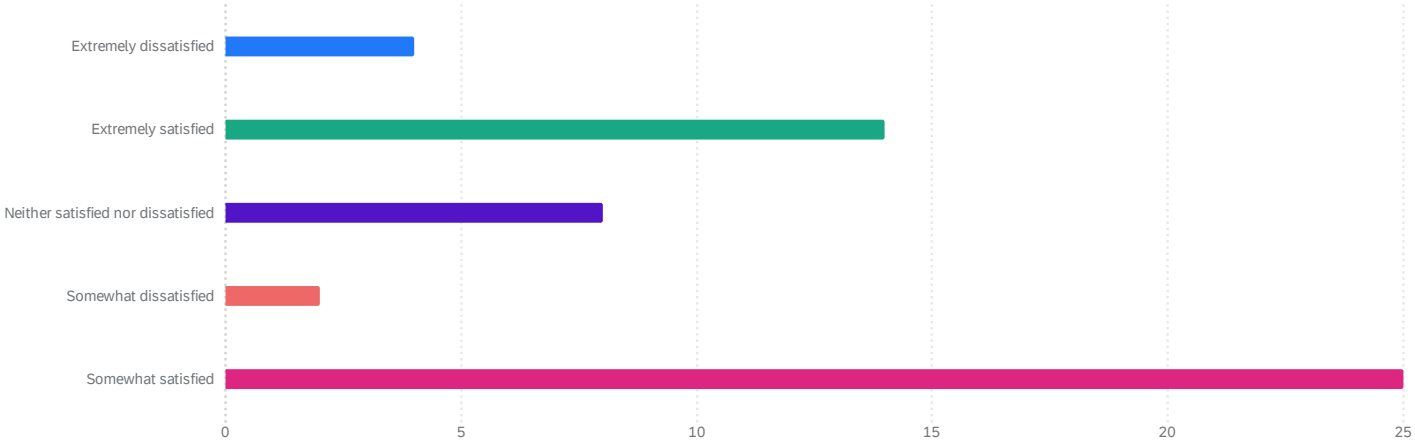
Confirmation scan was succesfull



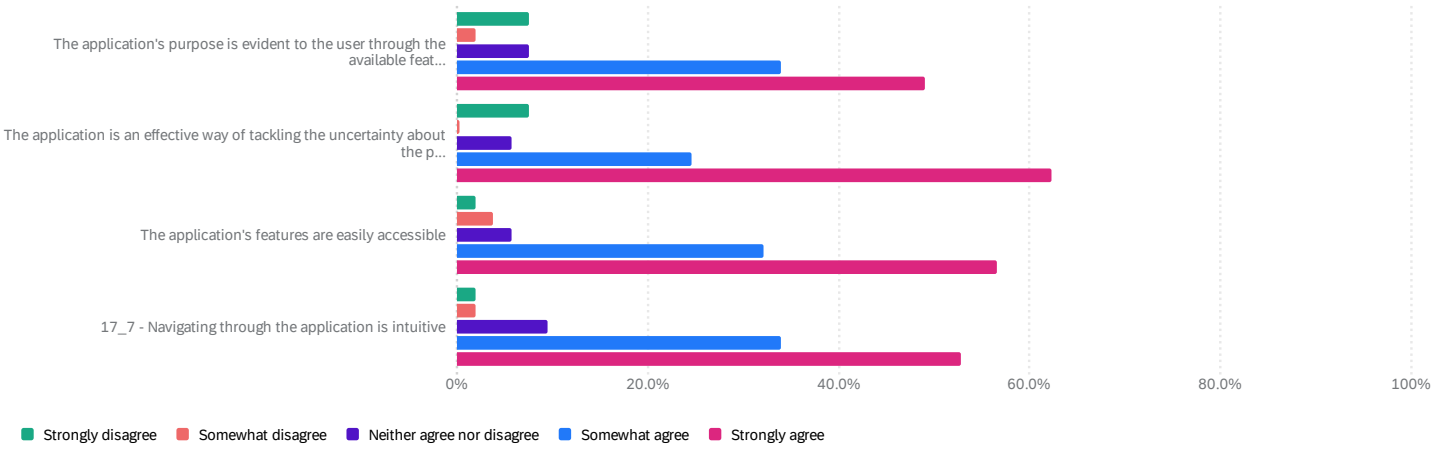
How satisfied are you with regards to the amount of information provided on the aliments' page?



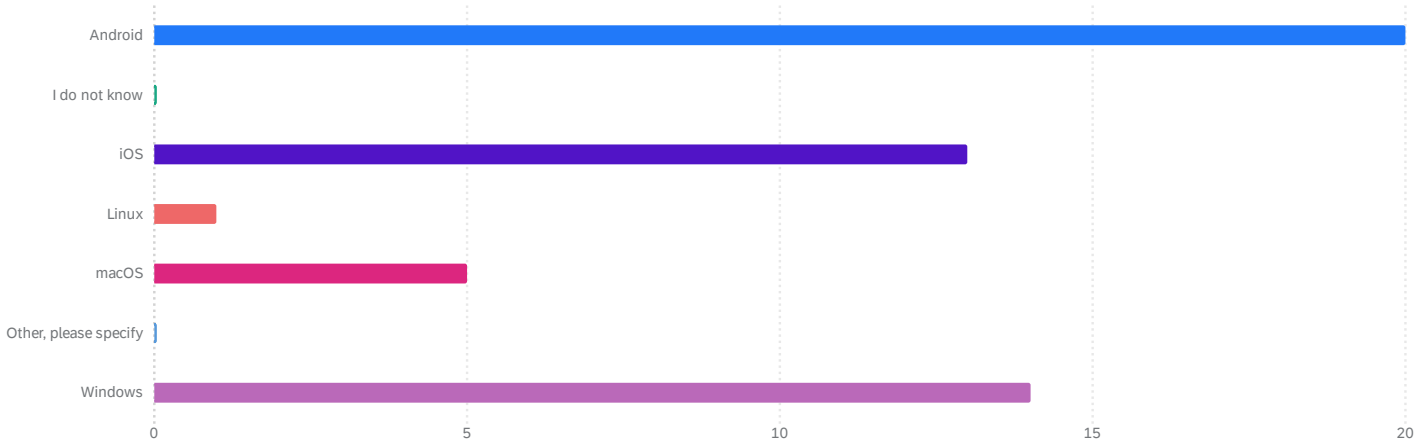
How satisfied are you with regards to the authenticity and security of the data after clicking on th



Please select the extent to which you agree with the following statements.



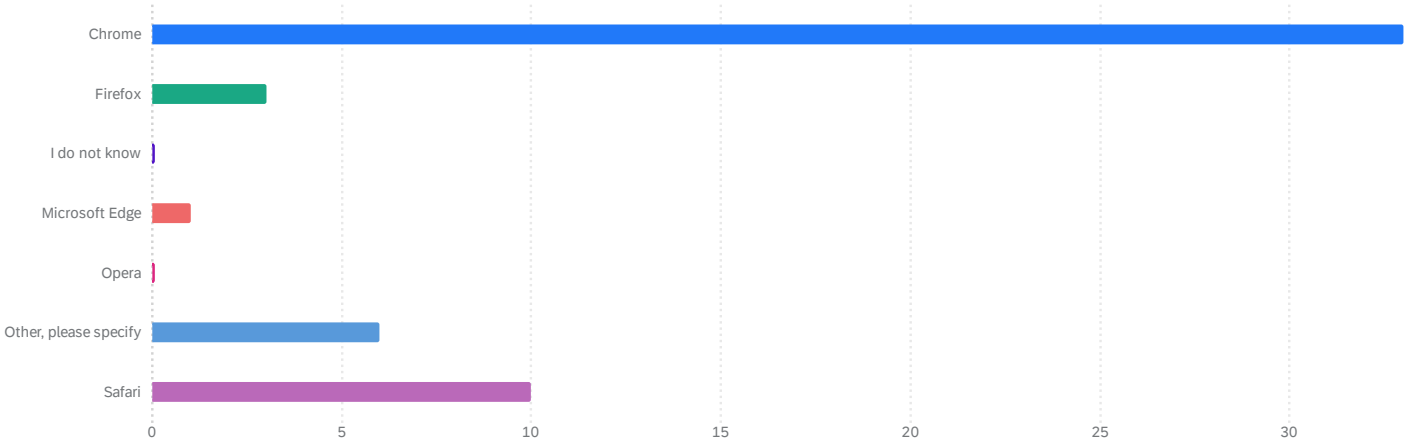
What Operating System have you used to check the application?



What Operating System have you used to check the application?: Other, please specify

No data found - your filters may be too exclusive!

What browser have you used to check the application?

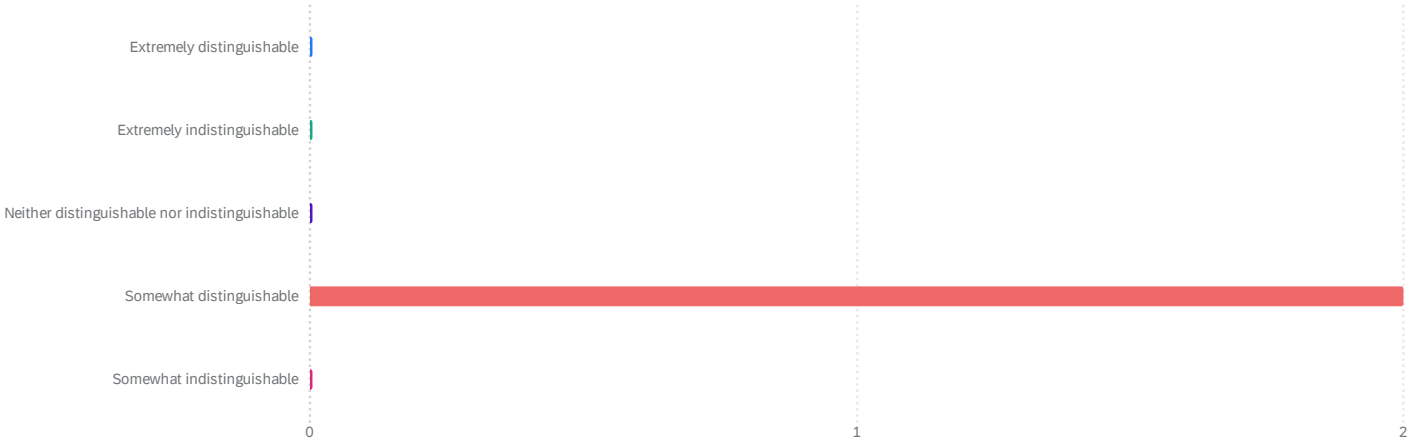


What browser have you used to check the application?: Other, please specify

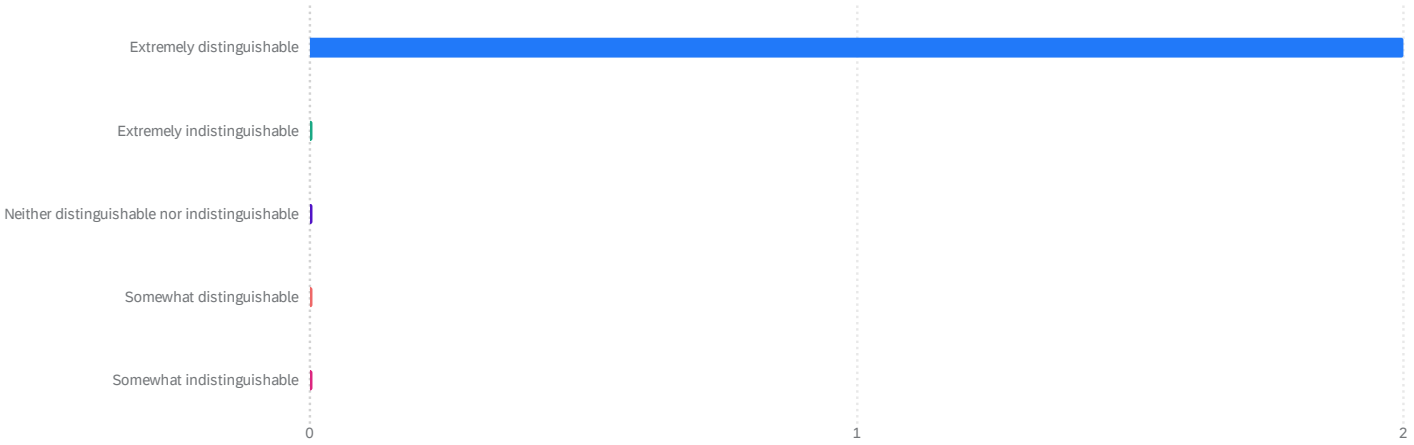
Brave
Ecosia
Samsung internet
Opera GX
Brave
Opera GX

As a user suffering from Protanopia, how distinguishable is the colour scheme used throughout the ap

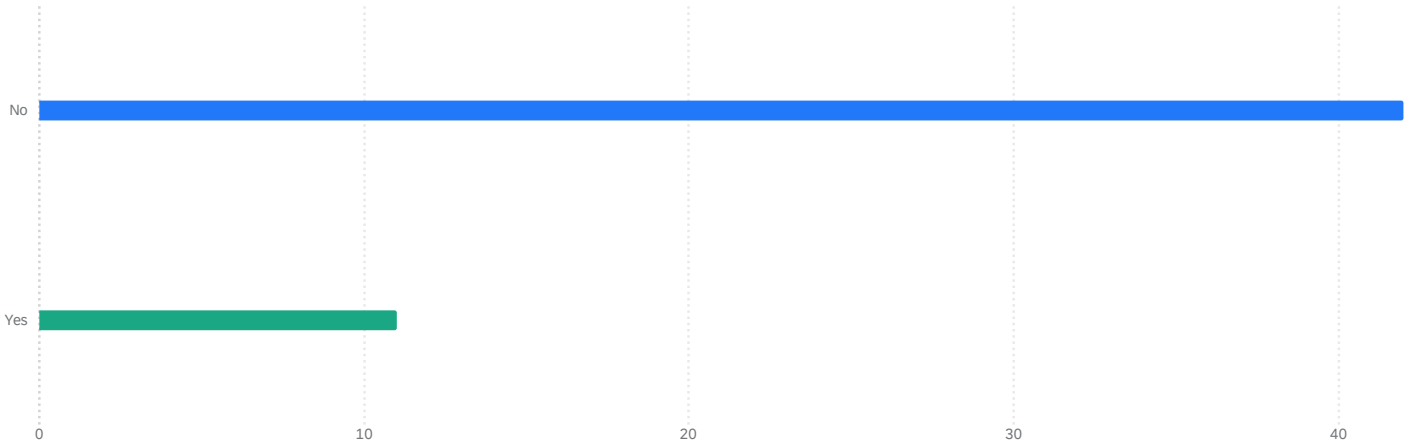
As a user suffering from Deuteranopia, how distinguishable is the colour scheme used throughout the



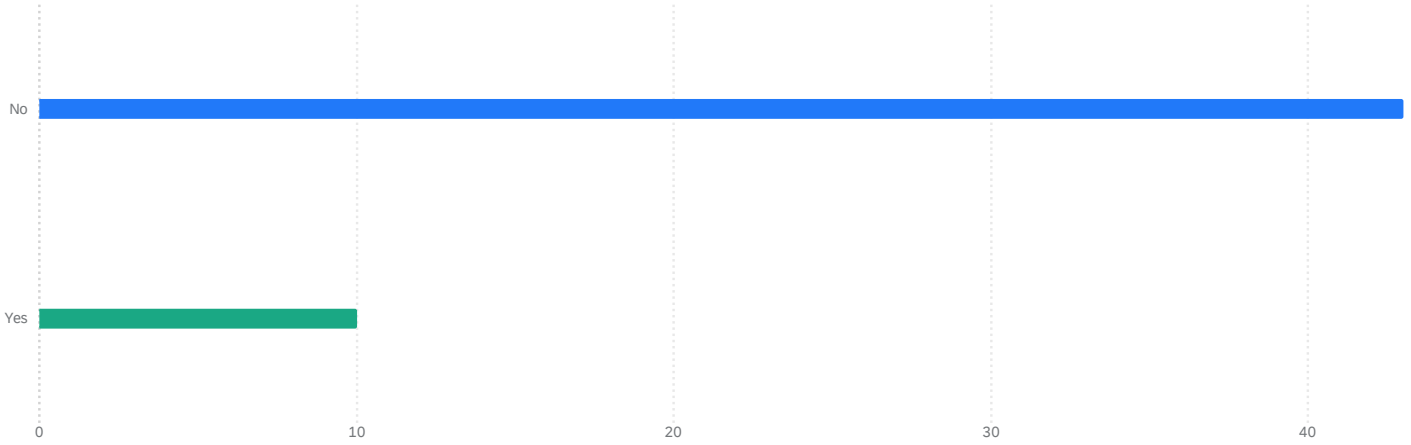
As a user suffering from Triteranopia, how distinguishable is the colour scheme used throughout the



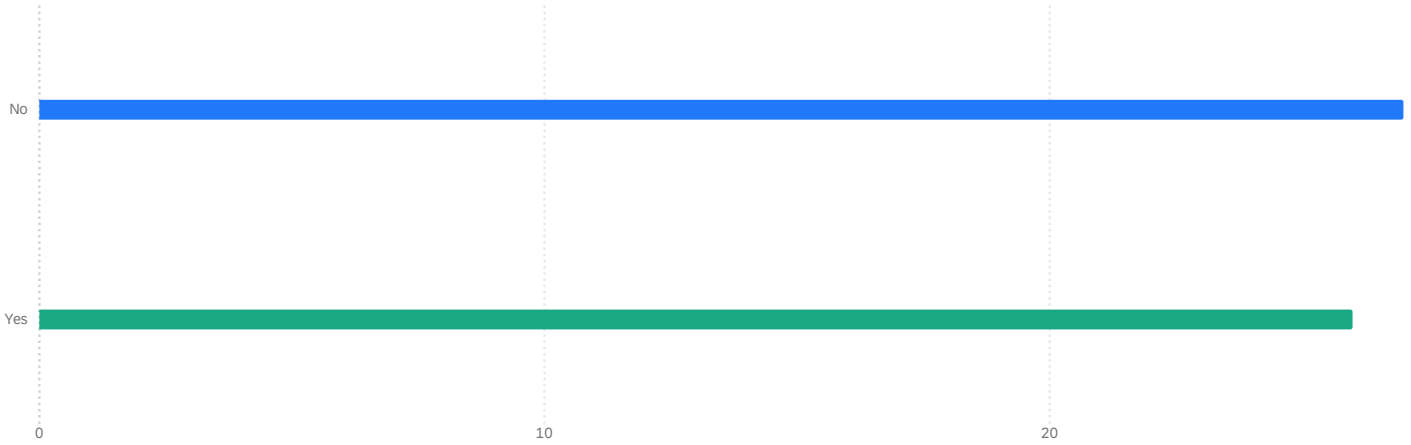
Have you at any point, changed the font size of the application?



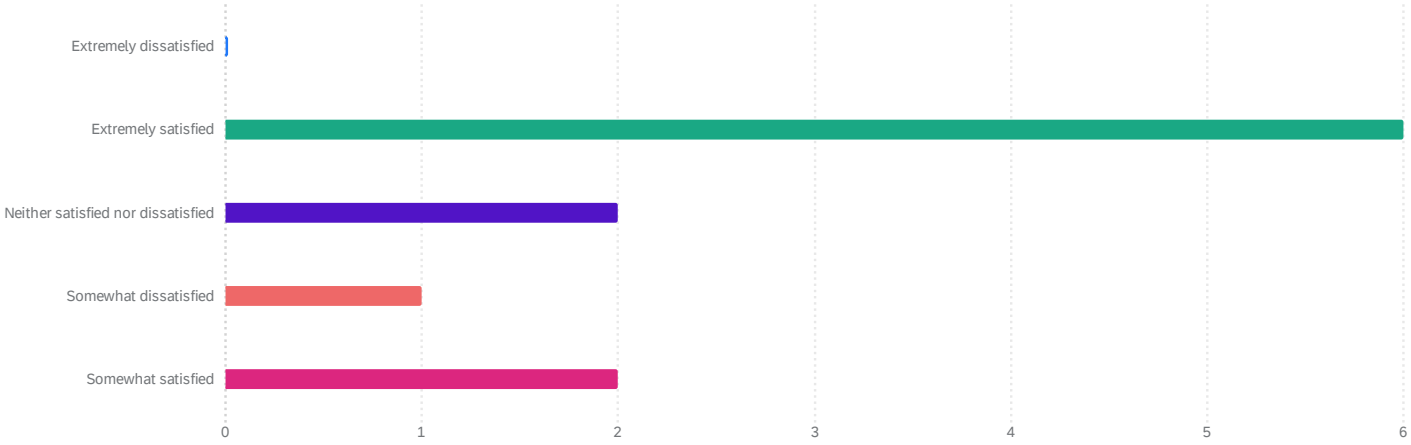
Have you used the application in another language other than English?



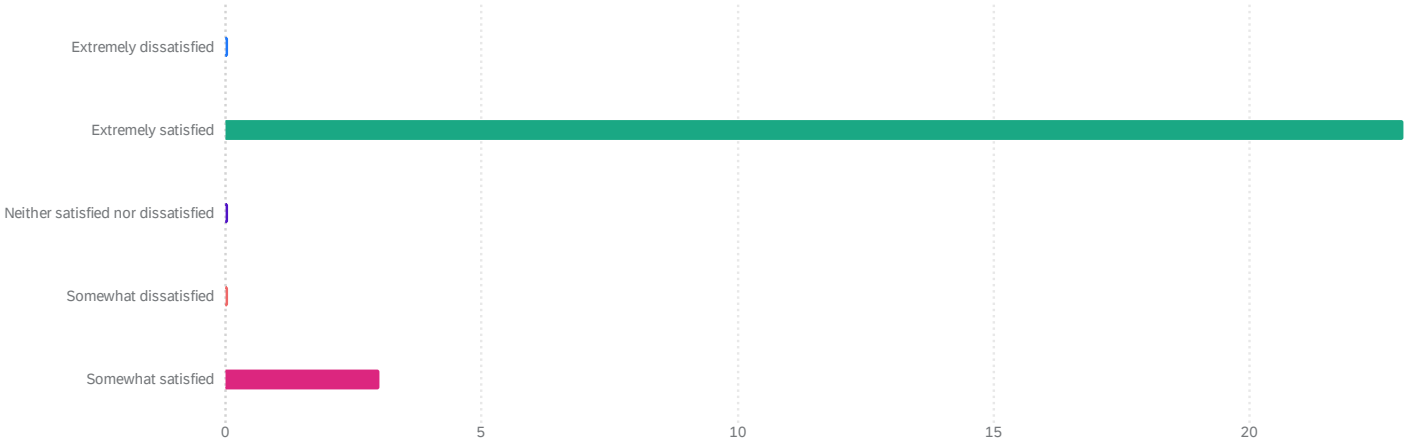
Have you at any point, used the application in high contrast mode (dark mode)?



How satisfied are you the applications' feature of changing the font size?



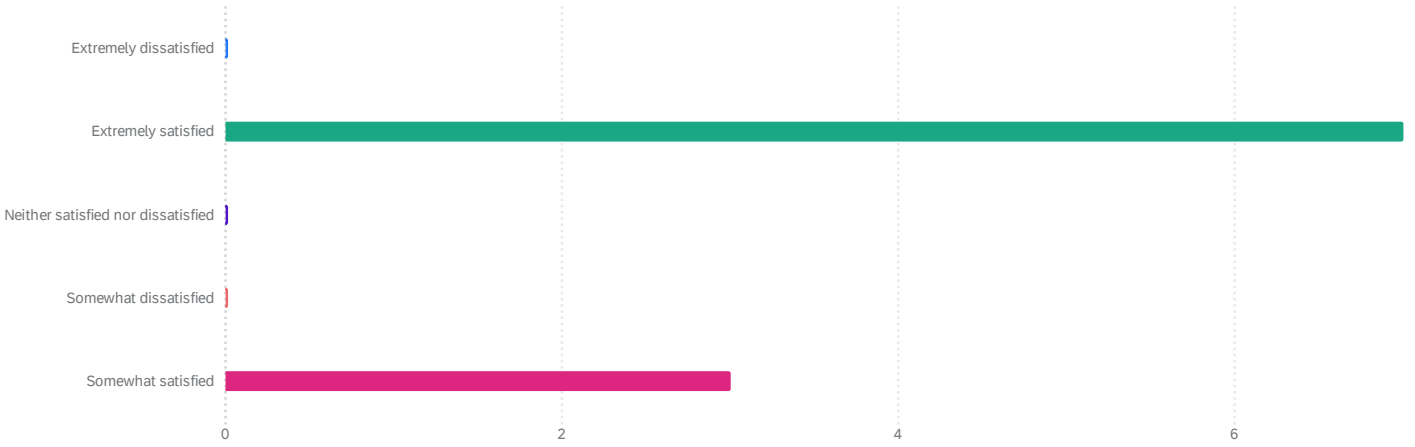
How satisfied are you the functionality of changing the contrast mode (dark mode)?



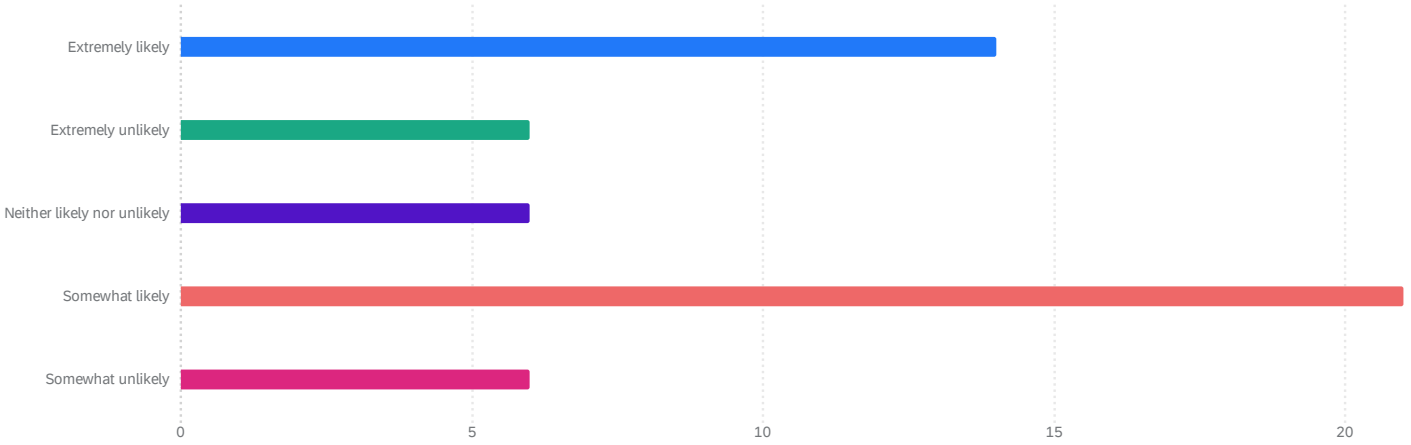
In what language have you used the application?

An unexpected error has occurred.

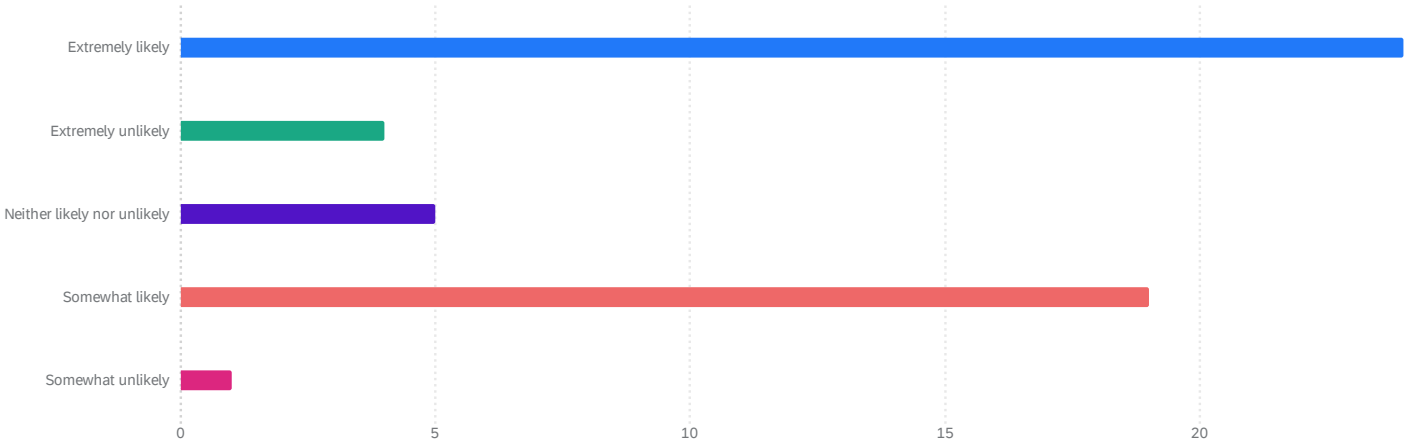
How satisfied are you with the quality of the translation?



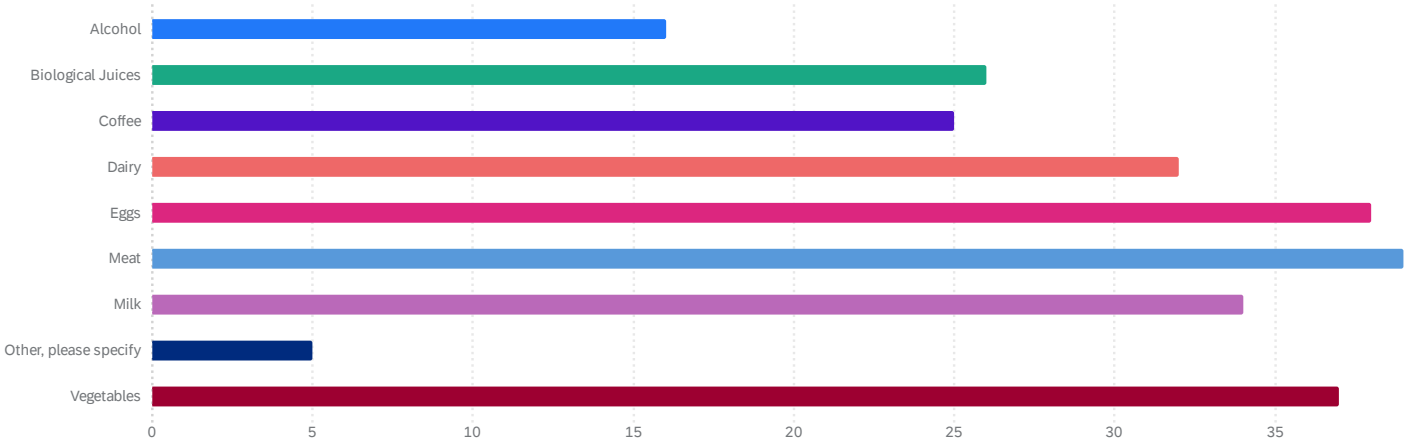
How likely would you be in using this application again?



How likely would you be in using this application if your local supermarket were to introduce it?



For what other types of products/aliments would you be interested in using this application for?



For what other types of products/aliments would you be interested in using this application for?: Other, please specify

Tofu

Anything, really, even processed sweets

chocolate

None

None

No more results to show

What kind of feature would you like to be implemented in this application?

Instant scanner, widget on homescreen

display the nutri-score, calculate and show the carbon footprint for "track journey" and "distribution" events

I would like to see the 'journey' of the product instead of separated map points for each stage of production. It would also be nice to just open the cam and make the app recognize products in store and fetch you it trace once it's certain what product it is

Certifications panel confusing

A category section of the products would be fairly useful

Do you have any other ideas on improving the application? Any feedback is much appreciated an

Make a widget

This app is quite novel and interesting. Good job!

It would definitely need another color palette. The white mode is basically google aesthetics and the dark mode is constrast-less. Other than that, well done!

No:) very creative idea

After using the app in Romanian, I went back to settings to change the font size and as soon as I got back to home screen the language changed back to English. Hopefully this will help you :)


Score
15
10
5
1

D Lighthouse Report

https://tracinglens.web.app/settings

Performance	Accessibility	Best Practices	SEO	PWA
90	100	100	80	—

There were issues affecting this run of Lighthouse:

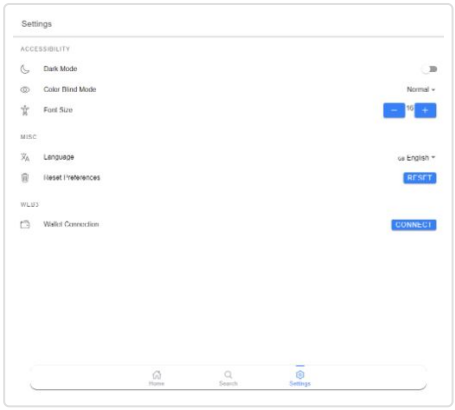
- **There may be stored data affecting loading performance in this location: IndexedDB. Audit this page in an incognito window to prevent those resources from affecting your scores.**

90

Performance

Values are estimated and may vary. The performance score is calculated directly from these metrics. See calculator.

▲ 0–49 50–89 90–100



METRICS Expand view

First Contentful Paint 1.0 s	Time to Interactive 1.2 s
Speed Index 1.4 s	Total Blocking Time 80 ms
Largest Contentful Paint 1.7 s	Cumulative Layout Shift 0.053

View Original Trace View Treemap

university of groningen / faculty of science and engineering / computing science

Show audits relevant to: All FCP TBT LCP CLS

OPPORTUNITIES

Opportunity	Estimated Savings
Reduce unused JavaScript	0.56 s

Reduce unused JavaScript and defer loading scripts until they are required to decrease bytes consumed by network activity. Learn more. LCP

If you are not server-side rendering, split your JavaScript bundles with `React.lazy()`. Otherwise, code-split using a third-party library such as loadable-components.

URL	Transfer Size	Potential Savings
/4025.0650a216…f9.js (tracinglens.web.app)	704.0 KiB	472.0 KiB
/main.e52bd2668d6df36b.js (tracinglens.web.app)	261.7 KiB	174.4 KiB
/6039.e9c13b9fee9bd571.js (tracinglens.web.app)	36.6 KiB	27.4 KiB

These suggestions can help your page load faster. They don't directly affect the Performance score.

DIAGNOSTICS

▲ Serve static assets with an efficient cache policy — 20 resources found

A long cache lifetime can speed up repeat visits to your page. Learn more.

☑ Show 3rd-party resources (1)

URL	Cache TTL	Transfer Size
…36/MetaMask_Fox.svg (upload.wikimedia.org)	None	2 KiB
/4025.0650a216…f9.js (tracinglens.web.app)	1 h	704 KiB
/main.e52bd2668d6df36b.js (tracinglens.web.app)	1 h	262 KiB

URL	Cache TTL	Transfer Size
/3880.f2bbd3e6db2fa0cd.js (tracinglens.web.app)	1 h	46 KiB
/6039.e9c13b9fee9bd571.js (tracinglens.web.app)	1 h	37 KiB
/polyfills.63caafea7e3cb544.js (tracinglens.web.app)	1 h	19 KiB
/53.e5915d4d92e873fc.js (tracinglens.web.app)	1 h	9 KiB
/4711.77c2b103….js (tracinglens.web.app)	1 h	8 KiB
/common.65dc49121cab3310.js (tracinglens.web.app)	1 h	6 KiB
…icon/favicon.png (tracinglens.web.app)	1 h	5 KiB
/styles.cf426811a496b68e.css (tracinglens.web.app)	1 h	5 KiB
/5652.9d1dbe724839cfbd.js (tracinglens.web.app)	1 h	5 KiB
/2773.f38fa6bf1d691c50.js (tracinglens.web.app)	1 h	4 KiB
/438.fa047ca01a3735a2.js (tracinglens.web.app)	1 h	3 KiB
/5168.7629017bd38b04d0.js (tracinglens.web.app)	1 h	3 KiB
/runtime.8274af5c1dfc198d.js (tracinglens.web.app)	1 h	3 KiB
/9958.f291f1c4e13a859b.js (tracinglens.web.app)	1 h	1 KiB
/5145.c4a9630b06eb3daa.js (tracinglens.web.app)	1 h	1 KiB
/9702.5248ecf0075d93e1.js (tracinglens.web.app)	1 h	1 KiB
/3262.66aab5e9802639cd.js (tracinglens.web.app)	1 h	1 KiB

○ Avoid chaining critical requests — 12 chains found

The Critical Request Chains below show you what resources are loaded with a high priority. Consider reducing the length of chains, reducing the download size of resources, or deferring the download of unnecessary resources to improve page load. Learn more. FCP LCP

Maximum critical path latency: **1,160 ms**

Initial Navigation

/settings (tracinglens.web.app)

/runtime.8274af5c1dfc198d.js (tracinglens.web.app) **- 130 ms, 2.61 KiB**

/polyfills.63caafea7e3cb544.js (tracinglens.web.app) **- 120 ms, 18.59 KiB**

/main.e52bd2668d6df36b.js (tracinglens.web.app)

/common.65dc49121cab3310.js (tracinglens.web.app) **- 110 ms, 5.91 KiB**

/53.e5915d4d92e873fc.js (tracinglens.web.app)

/3262.66aab5e9802639cd.js (tracinglens.web.app) **- 100 ms, 1.14 KiB**

/5145.c4a9630b06eb3daa.js (tracinglens.web.app)

/4025.0650a216…f9.js (tracinglens.web.app)

/6039.e9c13b9fee9bd571.js (tracinglens.web.app) **- 110 ms, 36.64 KiB**

/3880.f2bbd3e6db2fa0cd.js (tracinglens.web.app) **- 100 ms, 46.02 KiB**

/9702.5248ecf0075d93e1.js (tracinglens.web.app) **- 80 ms, 1.18 KiB**

/438.fa047ca01a3735a2.js (tracinglens.web.app)

/9958.f291f1c4e13a859b.js (tracinglens.web.app) **- 80 ms, 1.26 KiB**

/5652.9d1dbe724839cfbd.js (tracinglens.web.app) **- 60 ms, 4.60 KiB**

/4711.77c2b103….js (tracinglens.web.app) **- 100 ms, 8.36 KiB**

/5168.7629017bd38b04d0.js (tracinglens.web.app) **- 40 ms, 2.62 KiB**

/2773.f38fa6bf1d691c50.js (tracinglens.web.app) **- 140 ms, 4.30 KiB**

User Timing marks and measures — 31 user timings

Consider instrumenting your app with the User Timing API to measure your app's real-world performance during key user experiences. Learn more.

Use the React DevTools Profiler, which makes use of the Profiler API, to measure the rendering performance of your components. Learn more.

Name	Type	Start Time	Duration
Zone	Measure	176.23 ms	0.38 ms
Zone:ZoneAwarePromise	Measure	176.75 ms	0.46 ms
Zone:toString	Measure	177.26 ms	0.04 ms
Zone:util	Measure	177.38 ms	0.32 ms
Zone:timers	Measure	177.85 ms	0.05 ms

Name	Type	Start Time	Duration
Zone:blocking	Measure	178.09 ms	0.01 ms
Zone:EventTarget	Measure	178.15 ms	0.55 ms
Zone:MutationObserver	Measure	178.75 ms	0.05 ms
Zone:FileReader	Measure	179.03 ms	0.07 ms
Zone:on_property	Measure	179.17 ms	17.64 ms
Zone:customElements	Measure	196.88 ms	0.12 ms
Zone:XHR	Measure	197.06 ms	0.14 ms
Zone:geolocation	Measure	197.27 ms	0.14 ms
Zone	Mark	176.26 ms	
Zone:ZoneAwarePromise	Mark	176.75 ms	
Zone:toString	Mark	177.27 ms	
Zone:util	Mark	177.39 ms	
Zone:legacy	Mark	177.76 ms	
Zone:queueMicrotask	Mark	177.81 ms	
Zone:timers	Mark	177.85 ms	
Zone:requestAnimationFrame	Mark	178.02 ms	
Zone:blocking	Mark	178.09 ms	
Zone:EventTarget	Mark	178.16 ms	
Zone:MutationObserver	Mark	178.76 ms	
Zone:IntersectionObserver	Mark	178.92 ms	
Zone:FileReader	Mark	179.04 ms	

Name	Type	Start Time	Duration
Zone:on_property	Mark	179.17 ms	
Zone:customElements	Mark	196.88 ms	
Zone:XHR	Mark	197.07 ms	
Zone:geolocation	Mark	197.27 ms	
Zone:PromiseRejectionEvent	Mark	197.45 ms	

Keep request counts low and transfer sizes small — 34 requests • 1,140 KiB

To set budgets for the quantity and size of page resources, add a budget.json file. Learn more.

Resource Type	Requests	Transfer Size
Total	34	1,139.7 KiB
Script	17	1,112.5 KiB
Other	13	13.1 KiB
Image	2	7.6 KiB
Stylesheet	1	5.0 KiB
Document	1	1.5 KiB
Media	0	0.0 KiB
Font	0	0.0 KiB
Third-party	1	2.4 KiB

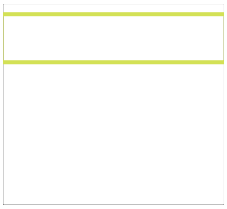
Largest Contentful Paint element — 1 element found

This is the largest contentful element painted within the viewport. Learn More LCP

Element	
	ion-label.sc-ion-label-md-h.sc-ion-label-md-s.md.hydrated

Avoid large layout shifts — 2 elements found

These DOM elements contribute most to the CLS of the page. CLS

Element	CLS Contribution
main.inner-scroll.scroll-y	0.04
 ion-list.md.list-md.list-lines-none.list-md-lines-none.hydrated	0.013

Avoid long main-thread tasks — 3 long tasks found

Lists the longest tasks on the main thread, useful for identifying worst contributors to input delay. Learn more TBT

URL	Start Time	Duration
/main.e52bd2668d6df36b.js (tracinglens.web.app)	670 ms	156 ms
/main.e52bd2668d6df36b.js (tracinglens.web.app)	831 ms	110 ms
/settings (tracinglens.web.app)	270 ms	101 ms

More information about the performance of your application. These numbers don't directly affect the Performance score.

PASSED AUDITS (32) Hide

Eliminate render-blocking resources

Resources are blocking the first paint of your page. Consider delivering critical JS/CSS inline and deferring all non-critical JS/styles. Learn more. FCP LCP

Properly size images

Serve images that are appropriately-sized to save cellular data and improve load time. Learn more.

Defer offscreen images

Consider lazy-loading offscreen and hidden images after all critical resources have finished loading to lower time to interactive. Learn more.

Minify CSS

Minifying CSS files can reduce network payload sizes. Learn more. FCP LCP

If your build system minifies CSS files automatically, ensure that you are deploying the production build of your application. You can check this with the React Developer Tools extension. Learn more.

Minify JavaScript

Minifying JavaScript files can reduce payload sizes and script parse time. Learn more. FCP LCP

If your build system minifies JS files automatically, ensure that you are deploying the production build of your application. You can check this with the React Developer Tools extension. Learn more.

Reduce unused CSS

Reduce unused rules from stylesheets and defer CSS not used for above-the-fold content to decrease bytes consumed by network activity. Learn more. FCP LCP

Efficiently encode images

Optimized images load faster and consume less cellular data. Learn more.

Serve images in next-gen formats

Image formats like WebP and AVIF often provide better compression than PNG or JPEG, which means faster downloads and less data consumption. Learn more.

Enable text compression

Text-based resources should be served with compression (gzip, deflate or brotli) to minimize total network bytes. Learn more. FCP LCP

Preconnect to required origins — Potential savings of 80 ms

Consider adding `preconnect` or `dns-prefetch` resource hints to establish early connections to important third-party origins. Learn more. FCP LCP

URL	Potential Savings
https://upload.wikimedia.org	80 ms

Initial server response time was short — Root document took 10 ms

Keep the server response time for the main document short because all other requests depend on it. Learn more. FCP LCP

If you are server-side rendering any React components, consider using `renderToNodeStream()` or `renderToStaticNodeStream()` to allow the client to receive and hydrate different parts of the markup instead of all at once. Learn more.

URL	Time Spent
/settings (tracinglens.web.app)	10 ms

Avoid multiple page redirects

Redirects introduce additional delays before the page can be loaded. Learn more. FCP LCP

If you are using React Router, minimize usage of the `<Redirect>` component for route navigations.

Preload key requests

Consider using `<link rel=preload>` to prioritize fetching resources that are currently requested later in page load. Learn more. FCP LCP

Use HTTP/2

HTTP/2 offers many benefits over HTTP/1.1, including binary headers and multiplexing. Learn more.

Use video formats for animated content

Large GIFs are inefficient for delivering animated content. Consider using MPEG4/WebM videos for animations and PNG/WebP for static images instead of GIF to save network bytes. Learn more LCP

Remove duplicate modules in JavaScript bundles

Remove large, duplicate JavaScript modules from bundles to reduce unnecessary bytes consumed by network activity. TBT

Avoid serving legacy JavaScript to modern browsers — Potential savings of 5 KiB

Polyfills and transforms enable legacy browsers to use new JavaScript features. However, many aren't necessary for modern browsers. For your bundled JavaScript, adopt a modern script deployment strategy using module/nomodule feature detection to reduce the amount of code shipped to modern browsers, while retaining support for legacy browsers. Learn More TBT

URL		Potential Savings
/4025.0650a216…f9.js (tracinglens.web.app)		4.8 KiB
4025.0650a216141549f9.js:1	`@babel/plugin-transform-classes`	
4025.0650a216141549f9.js:1	`Array.isArray`	
4025.0650a216141549f9.js:1	`Object.keys`	
/main.e52bd2668d6df36b.js (tracinglens.web.app)		0.0 KiB
main.e52bd2668d6df36b.js:1	`@babel/plugin-transform-classes`	

Preload Largest Contentful Paint image

Preload the image used by the LCP element in order to improve your LCP time. Learn more. LCP

Avoids enormous network payloads — Total size was 1,140 KiB

Large network payloads cost users real money and are highly correlated with long load times. Learn more. LCP

URL	Transfer Size
/4025.0650a216…f9.js (tracinglens.web.app)	704.0 KiB
/main.e52bd2668d6df36b.js (tracinglens.web.app)	261.7 KiB

URL	Transfer Size
/3880.f2bbd3e6db2fa0cd.js (tracinglens.web.app)	46.0 KiB
/6039.e9c13b9fee9bd571.js (tracinglens.web.app)	36.6 KiB
/polyfills.63caafea7e3cb544.js (tracinglens.web.app)	18.6 KiB
/53.e5915d4d92e873fc.js (tracinglens.web.app)	9.2 KiB
/4711.77c2b103….js (tracinglens.web.app)	8.4 KiB
/common.65dc49121cab3310.js (tracinglens.web.app)	5.9 KiB
…icon/favicon.png (tracinglens.web.app)	5.2 KiB
…icon/favicon.png (tracinglens.web.app)	5.2 KiB

Avoids an excessive DOM size — 314 elements

A large DOM will increase memory usage, cause longer style calculations, and produce costly layout reflows. Learn more. TBT

Consider using a "windowing" library like `react-window` to minimize the number of DOM nodes created if you are rendering many repeated elements on the page. Learn more. Also, minimize unnecessary re-renders using `shouldComponentUpdate`, `PureComponent`, or `React.memo` and skip effects only until certain dependencies have changed if you are using the `Effect` hook to improve runtime performance.

Statistic	Element	Value
Total DOM Elements		314
Maximum DOM Depth	title	19
Maximum Child Elements	ion-content.md.content-ltr.hydrated	8

JavaScript execution time — 0.6 s

Consider reducing the time spent parsing, compiling, and executing JS. You may find delivering smaller JS payloads helps with this. Learn more. TBT

URL	Total CPU Time	Script Evaluation	Script Parse
/main.e52bd2668d6df36b.js (tracinglens.web.app)	420 ms	403 ms	2 ms
/settings (tracinglens.web.app)	190 ms	77 ms	29 ms
Unattributable	143 ms	27 ms	0 ms
/polyfills.63caafea7e3cb544.js (tracinglens.web.app)	90 ms	86 ms	0 ms

Minimizes main-thread work — 0.9 s

Consider reducing the time spent parsing, compiling and executing JS. You may find delivering smaller JS payloads helps with this. Learn more TBT

Category	Time Spent
Script Evaluation	624 ms
Other	154 ms
Style & Layout	60 ms
Script Parsing & Compilation	37 ms
Parse HTML & CSS	16 ms
Garbage Collection	12 ms
Rendering	7 ms

All text remains visible during webfont loads

Leverage the font-display CSS feature to ensure text is user-visible while webfonts are loading. Learn more. FCP LCP

Minimize third-party usage

Third-party code can significantly impact load performance. Limit the number of redundant third-party providers and try to load third-party code after your page has primarily finished loading. Learn more. TBT

Lazy load third-party resources with facades

Lazy load third-party resources with facades

Some third-party embeds can be lazy loaded. Consider replacing them with a facade until they are required. Learn more. TBT

Largest Contentful Paint image was not lazily loaded

Above-the-fold images that are lazily loaded render later in the page lifecycle, which can delay the largest contentful paint. Learn more.

Uses passive listeners to improve scrolling performance

Consider marking your touch and wheel event listeners as `passive` to improve your page's scroll performance. Learn more.

Avoids `document.write()`

For users on slow connections, external scripts dynamically injected via `document.write()` can delay page load by tens of seconds. Learn more.

Avoid non-composited animations

Animations which are not composited can be janky and increase CLS. Learn more CLS

Image elements have explicit `width` and `height`

Set an explicit width and height on image elements to reduce layout shifts and improve CLS. Learn more CLS

Has a `<meta name="viewport">` tag with `width` or `initial-scale`

A `<meta name="viewport">` not only optimizes your app for mobile screen sizes, but also prevents a 300 millisecond delay to user input. Learn more. TBT

Avoids `unload` event listeners

The `unload` event does not fire reliably and listening for it can prevent browser optimizations like the Back-Forward Cache. Use `pagehide` or `visibilitychange` events instead. Learn more

Accessibility

Accessibility

These checks highlight opportunities to improve the accessibility of your web app. Only a subset of accessibility issues can be automatically detected so manual testing is also encouraged.

ADDITIONAL ITEMS TO MANUALLY CHECK (10)

Hide

- The page has a logical tab order
  - Tabbing through the page follows the visual layout. Users cannot focus elements that are offscreen. Learn more.
- Interactive controls are keyboard focusable
  - Custom interactive controls are keyboard focusable and display a focus indicator. Learn more.
- Interactive elements indicate their purpose and state
  - Interactive elements, such as links and buttons, should indicate their state and be distinguishable from non-interactive elements. Learn more.
- The user's focus is directed to new content added to the page
  - If new content, such as a dialog, is added to the page, the user's focus is directed to it. Learn more.
- User focus is not accidentally trapped in a region
  - A user can tab into and out of any control or region without accidentally trapping their focus. Learn more.
- Custom controls have associated labels
  - Custom interactive controls have associated labels, provided by aria-label or aria-labelledby. Learn more.
- Custom controls have ARIA roles
  - Custom interactive controls have appropriate ARIA roles. Learn more.
- Visual order on the page follows DOM order
  - DOM order matches the visual order, improving navigation for assistive technology. Learn more.
- Offscreen content is hidden from assistive technology
  - Offscreen content is hidden with display: none or aria-hidden=true. Learn more.

- HTML5 landmark elements are used to improve navigation

  Landmark elements (<main>, <nav>, etc.) are used to improve the keyboard navigation of the page for assistive technology. Learn more.

These items address areas which an automated testing tool cannot cover. Learn more in our guide on conducting an accessibility review.

PASSED AUDITS (21) Hide

- `[aria-*]` attributes match their roles

  Each ARIA `role` supports a specific subset of `aria-*` attributes. Mismatching these invalidates the `aria-*` attributes. Learn more.

- `[aria-hidden="true"]` is not present on the document `<body>`

  Assistive technologies, like screen readers, work inconsistently when `aria-hidden="true"` is set on the document `<body>`. Learn more.

- `[role]`s have all required `[aria-*]` attributes

  Some ARIA roles have required attributes that describe the state of the element to screen readers. Learn more.

- Elements with an ARIA `[role]` that require children to contain a specific `[role]` have all required children.

  Some ARIA parent roles must contain specific child roles to perform their intended accessibility functions. Learn more.

- `[role]`s are contained by their required parent element

  Some ARIA child roles must be contained by specific parent roles to properly perform their intended accessibility functions. Learn more.

- `[role]` values are valid

  ARIA roles must have valid values in order to perform their intended accessibility functions. Learn more.

- `[aria-*]` attributes have valid values

  Assistive technologies, like screen readers, can't interpret ARIA attributes with invalid values. Learn more.

- `[aria-*]` attributes are valid and not misspelled

Assistive technologies, like screen readers, can't interpret ARIA attributes with invalid names. Learn more.

Buttons have an accessible name

When a button doesn't have an accessible name, screen readers announce it as "button", making it unusable for users who rely on screen readers. Learn more.

ARIA IDs are unique

The value of an ARIA ID must be unique to prevent other instances from being overlooked by assistive technologies. Learn more.

Form elements have associated labels

Labels ensure that form controls are announced properly by assistive technologies, like screen readers. Learn more.

`[user-scalable="no"]` is not used in the `<meta name="viewport">` element and the `[maximum-scale]` attribute is not less than 5.

Disabling zooming is problematic for users with low vision who rely on screen magnification to properly see the contents of a web page. Learn more.

`button`, `link`, and `menuitem` elements have accessible names

When an element doesn't have an accessible name, screen readers announce it with a generic name, making it unusable for users who rely on screen readers. Learn more.

`[aria-hidden="true"]` elements do not contain focusable descendents

Focusable descendents within an `[aria-hidden="true"]` element prevent those interactive elements from being available to users of assistive technologies like screen readers. Learn more.

ARIA toggle fields have accessible names

When a toggle field doesn't have an accessible name, screen readers announce it with a generic name, making it unusable for users who rely on screen readers. Learn more.

Background and foreground colors have a sufficient contrast ratio

Low-contrast text is difficult or impossible for many users to read. Learn more.

Document has a `<title>` element

Document has a `<title>` element

The title gives screen reader users an overview of the page, and search engine users rely on it heavily to determine if a page is relevant to their search. Learn more.

`[id]` attributes on active, focusable elements are unique

All focusable elements must have a unique `id` to ensure that they're visible to assistive technologies. Learn more.

`<html>` element has a `[lang]` attribute

If a page doesn't specify a lang attribute, a screen reader assumes that the page is in the default language that the user chose when setting up the screen reader. If the page isn't actually in the default language, then the screen reader might not announce the page's text correctly. Learn more.

`<html>` element has a valid value for its `[lang]` attribute

Specifying a valid BCP 47 language helps screen readers announce text properly. Learn more.

No element has a `[tabindex]` value greater than 0

A value greater than 0 implies an explicit navigation ordering. Although technically valid, this often creates frustrating experiences for users who rely on assistive technologies. Learn more.

NOT APPLICABLE (23) Hide

`[accesskey]` values are unique

Access keys let users quickly focus a part of the page. For proper navigation, each access key must be unique. Learn more.

ARIA input fields have accessible names

When an input field doesn't have an accessible name, screen readers announce it with a generic name, making it unusable for users who rely on screen readers. Learn more.

ARIA `meter` elements have accessible names

When an element doesn't have an accessible name, screen readers announce it with a generic name, making it unusable for users who rely on screen readers. Learn more.

ARIA `progressbar` elements have accessible names

When a `progressbar` element doesn't have an accessible name, screen readers announce it with a generic name, making it unusable for users who rely on screen readers. Learn more.

- ARIA `tooltip` elements have accessible names

When an element doesn't have an accessible name, screen readers announce it with a generic name, making it unusable for users who rely on screen readers. Learn more.

- ARIA `treeitem` elements have accessible names

When an element doesn't have an accessible name, screen readers announce it with a generic name, making it unusable for users who rely on screen readers. Learn more.

- The page contains a heading, skip link, or landmark region

Adding ways to bypass repetitive content lets keyboard users navigate the page more efficiently. Learn more.

- `<dl>`'s contain only properly-ordered `<dt>` and `<dd>` groups, `<script>`, `<template>` or `<div>` elements.

When definition lists are not properly marked up, screen readers may produce confusing or inaccurate output. Learn more.

- Definition list items are wrapped in `<dl>` elements

Definition list items (`<dt>` and `<dd>`) must be wrapped in a parent `<dl>` element to ensure that screen readers can properly announce them. Learn more.

- No form fields have multiple labels

Form fields with multiple labels can be confusingly announced by assistive technologies like screen readers which use either the first, the last, or all of the labels. Learn more.

- `<frame>` or `<iframe>` elements have a title

Screen reader users rely on frame titles to describe the contents of frames. Learn more.

- Heading elements appear in a sequentially-descending order

Properly ordered headings that do not skip levels convey the semantic structure of the page, making it easier to navigate and understand when using assistive technologies. Learn more.

- Image elements have `[alt]` attributes

Informative elements should aim for short, descriptive alternate text. Decorative elements can be ignored with an empty alt attribute. Learn more.

- `<input type="image">` elements have `[alt]` text

When an image is being used as an `<input>` button, providing alternative text can help screen reader users understand the purpose of the button. Learn more.

- Links have a discernible name

Link text (and alternate text for images, when used as links) that is discernible, unique, and focusable improves the navigation experience for screen reader users. Learn more.

- Lists contain only `<li>` elements and script supporting elements (`<script>` and `<template>`).

Screen readers have a specific way of announcing lists. Ensuring proper list structure aids screen reader output. Learn more.

- List items (`<li>`) are contained within `<ul>` or `<ol>` parent elements

Screen readers require list items (`<li>`) to be contained within a parent `<ul>` or `<ol>` to be announced properly. Learn more.

- The document does not use `<meta http-equiv="refresh">`

Users do not expect a page to refresh automatically, and doing so will move focus back to the top of the page. This may create a frustrating or confusing experience. Learn more.

- `<object>` elements have alternate text

Screen readers cannot translate non-text content. Adding alternate text to `<object>` elements helps screen readers convey meaning to users. Learn more.

- Cells in a `<table>` element that use the `[headers]` attribute refer to table cells within the same table.

Screen readers have features to make navigating tables easier. Ensuring `<td>` cells using the `[headers]` attribute only refer to other cells in the same table may improve the experience for screen reader users. Learn more.

- `<th>` elements and elements with `[role="columnheader"/"rowheader"]` have data cells they describe.

Screen readers have features to make navigating tables easier. Ensuring table headers always refer to some set of cells may improve the experience for screen reader users. Learn more.

- [lang] attributes have a valid value

  Specifying a valid BCP 47 language on elements helps ensure that text is pronounced correctly by a screen reader. Learn more.

- <video> elements contain a <track> element with [kind="captions"]

  When a video provides a caption it is easier for deaf and hearing impaired users to access its information. Learn more.

Best Practices

TRUST AND SAFETY

- Ensure CSP is effective against XSS attacks

  A strong Content Security Policy (CSP) significantly reduces the risk of cross-site scripting (XSS) attacks. Learn more

Description	Directive	Severity
No CSP found in enforcement mode		High

GENERAL

- Detected JavaScript libraries

  All front-end JavaScript libraries detected on the page. Learn more.

Name	Version
React	
Angular	14.0.5

- Missing source maps for large first-party JavaScript

Source maps translate minified code to the original source code. This helps developers debug in production. In addition, Lighthouse is able to provide further insights. Consider deploying source maps to take advantage of these benefits. Learn more.

URL	Map URL
/main.e52bd2668d6df36b.js (tracinglens.web.app) `Large JavaScript file is missing a source map`	
/4025.0650a216…f9.js (tracinglens.web.app) `Large JavaScript file is missing a source map`	

PASSED AUDITS (12) Hide

Uses HTTPS

All sites should be protected with HTTPS, even ones that don't handle sensitive data. This includes avoiding mixed content, where some resources are loaded over HTTP despite the initial request being served over HTTPS. HTTPS prevents intruders from tampering with or passively listening in on the communications between your app and your users, and is a prerequisite for HTTP/2 and many new web platform APIs. Learn more.

Avoids requesting the geolocation permission on page load

Users are mistrustful of or confused by sites that request their location without context. Consider tying the request to a user action instead. Learn more.

Avoids requesting the notification permission on page load

Users are mistrustful of or confused by sites that request to send notifications without context. Consider tying the request to user gestures instead. Learn more.

Avoids front-end JavaScript libraries with known security vulnerabilities

Some third-party scripts may contain known security vulnerabilities that are easily identified and exploited by attackers. Learn more.

Allows users to paste into password fields

Preventing password pasting undermines good security policy. Learn more.

Displays images with correct aspect ratio

Image display dimensions should match natural aspect ratio. Learn more.

Serves images with appropriate resolution

Image natural dimensions should be proportional to the display size and the pixel ratio to maximize image clarity. Learn more.

Page has the HTML doctype

Specifying a doctype prevents the browser from switching to quirks-mode. Learn more.

Properly defines charset

A character encoding declaration is required. It can be done with a `<meta>` tag in the first 1024 bytes of the HTML or in the Content-Type HTTP response header. Learn more.

Avoids deprecated APIs

Deprecated APIs will eventually be removed from the browser. Learn more.

No browser errors logged to the console

Errors logged to the console indicate unresolved problems. They can come from network request failures and other browser concerns. Learn more

No issues in the `Issues` panel in Chrome Devtools

Issues logged to the `Issues` panel in Chrome Devtools indicate unresolved problems. They can come from network request failures, insufficient security controls, and other browser concerns. Open up the Issues panel in Chrome DevTools for more details on each issue.

NOT APPLICABLE (1) Hide

Fonts with `font-display: optional` are preloaded

Preload `optional` fonts so first-time visitors may use them. Learn more

university of groningen / faculty of science and engineering / computing science

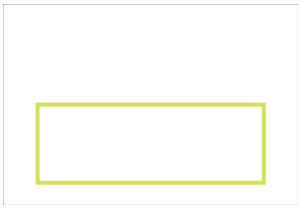
SEO

These checks ensure that your page is following basic search engine optimization advice. There are many additional factors Lighthouse does not score here that may affect your search ranking, including performance on Core Web Vitals. Learn more.

CRAWLING AND INDEXING

▲ Links are not crawlable

Search engines may use `href` attributes on links to crawl websites. Ensure that the `href` attribute of anchor elements links to an appropriate destination, so more pages of the site can be discovered. Learn More

Uncrawlable Link	
	a.button-native
	a.button-native
	a.button-native

▲ robots.txt is not valid — 18 errors found

If your robots.txt file is malformed, crawlers may not be able to understand how you want your website to be crawled or indexed. Learn more.

Line #	Content	Error
104		

Line #	Content	Error
1	`<!DOCTYPE html><html lang="en"><head>`	Syntax not understood
2	`<meta charset="utf-8">`	Syntax not understood
3	`<title>Tracing Lens</title>`	Syntax not understood
5	`<base href="/">`	Syntax not understood
7	`<meta name="color-scheme" content="light dark">`	Syntax not understood
8	`<meta name="viewport" content="viewport-fit=cover, width=device-width, initial-scale=1.0">`	Syntax not understood
9	`<meta name="format-detection" content="telephone=no">`	Syntax not understood
10	`<meta name="msapplication-tap-highlight" content="no">`	Syntax not understood
11	`<meta name="description" content="Tracing Lens - An application to check the provenance of your groceries from farm to table">`	Syntax not understood
13	`<link rel="icon" type="image/png" href="assets/icon/favicon.png">`	Syntax not understood
15	`<!-- add to homescreen for ios -->`	Syntax not understood
16	`<meta name="apple-mobile-web-app-capable" content="yes">`	Syntax not understood
17	`<meta name="apple-mobile-web-app-status-bar-style" content="black">`	Syntax not understood
18	`<style>:root{--ion-background-color:#ffffff;--ion-color-primary:#3880ff;--ion-color-primary-rgb:56, 128, 255;--ion-color-primary-contrast:#ffffff;--ion-color-primary-contrast-rgb:255, 255, 255;--ion-color-primary-shade:#3171e0;--ion-color-primary-tint:#4c8dff;--ion-color-secondary:#3dc2ff;--ion-color-secondary-rgb:61,`	Unknown directive

Line #	Content	Error

194, 255;--ion-color-secondary-contrast:#ffffff;--ion-color-secondary-contrast-rgb:255, 255, 255;--ion-color-secondary-shade:#36abe0;--ion-color-secondary-tint:#50c8ff;--ion-color-tertiary:#5260ff;--ion-color-tertiary-rgb:82, 96, 255;--ion-color-tertiary-contrast:#ffffff;--ion-color-tertiary-contrast-rgb:255, 255, 255;--ion-color-tertiary-shade:#4854e0;--ion-color-tertiary-tint:#6370ff;--ion-color-success:#2dd36f;--ion-color-success-rgb:45, 211, 111;--ion-color-success-contrast:#ffffff;--ion-color-success-contrast-rgb:255, 255, 255;--ion-color-success-shade:#28ba62;--ion-color-success-tint:#42d77d;--ion-color-warning:#ffc409;--ion-color-warning-rgb:255, 196, 9;--ion-color-warning-contrast:#000000;--ion-color-warning-contrast-rgb:0, 0, 0;--ion-color-warning-shade:#e0ac08;--ion-color-warning-tint:#ffca22;--ion-color-danger:#eb445a;--ion-color-danger-rgb:235, 68, 90;--ion-color-danger-contrast:#ffffff;--ion-color-danger-contrast-rgb:255, 255, 255;--ion-color-danger-shade:#cf3c4f;--ion-color-danger-tint:#ed576b;--ion-color-dark:#222428;--ion-color-dark-rgb:34, 36, 40;--ion-color-dark-contrast:#ffffff;--ion-color-dark-contrast-rgb:255, 255, 255;--ion-color-dark-shade:#1e2023;--ion-color-dark-tint:#383a3e;--ion-color-medium:#92949c;--ion-color-medium-rgb:146, 148, 156;--ion-color-medium-contrast:#ffffff;--ion-color-medium-contrast-rgb:255, 255, 255;--ion-color-medium-shade:#808289;--ion-color-medium-tint:#9d9fa6;--ion-color-light:#f4f5f8;--ion-color-light-rgb:244, 245, 248;--ion-color-light-contrast:#000000;--ion-color-light-contrast-rgb:0, 0, 0;--ion-color-light-shade:#d7d8da;--ion-color-light-tint:#f5f6f9}html{--ion-font-family:var(--ion-default-font)}body{background:var(--ion-background-color)}@supports (padding-top: 20px){html{--ion-safe-area-top:var(--ion-statusbar-padding)}}@supports (padding-top: constant(safe-area-inset-top)){html{--ion-safe-area-top:constant(safe-area-inset-top);--ion-safe-area-bottom:constant(safe-area-inset-bottom);--ion-safe-area-left:constant(safe-area-inset-left);--ion-safe-area-right:constant(safe-area-inset-right)}}@supports (padding-top: env(safe-area-inset-top)){html{--ion-safe-area-top:env(safe-area-inset-top);--ion-safe-area-bottom:env(safe-area-inset-bottom);--ion-safe-area-left:env(safe-area-inset-left);--ion-safe-area-right:env(safe-area-inset-right)}}*{box-sizing:border-box;-webkit-tap-highlight-color:rgba(0,0,0,0);-webkit-tap-highlight-color:transparent;-webkit-touch-callout:none}html{width:100%;height:100%;-webkit-text-size-adjust:100%;text-size-adjust:100%}html:not(.hydrated) body{display:none}body{-moz-osx-font-smoothing:grayscale;-webkit-font-smoothing:antialiased;margin:0;padding:0;position:fixed;width:100%;max-width:100%;height:100%;max-height:100%;transform:translateZ(0);text-rendering:optimizeLegibility;overflow:hidden;touch-action:manipulation;-webkit-user-drag:none;-ms-content-zooming:none;word-wrap:break-word;overscroll-behavior-y:none;-webkit-text-size-adjust:none;text-size-adjust:none}html{font-family:var(--ion-font-family)}</style><link rel="stylesheet" href="styles.cf426811a496b68e.css" media="print" onload="this.media='all'"><noscript><link rel="stylesheet" href="styles.cf426811a496b68e.css"></noscript></head>

Line #	Content	Error
20	`<body>`	Syntax not understood
21	`<app-root></app-root>`	Syntax not understood
22	`<script src="runtime.8274af5c1dfc198d.js" type="module"></script><script src="polyfills.63caafea7e3cb544.js" type="module"></script><script src="main.e52bd2668d6df36b.js" type="module"></script>`	Syntax not understood
24	`</body></html>`	Syntax not understood

To appear in search results, crawlers need access to your app.

ADDITIONAL ITEMS TO MANUALLY CHECK (1) Hide

- Structured data is valid

Run the Structured Data Testing Tool and the Structured Data Linter to validate structured data. Learn more.

Run these additional validators on your site to check additional SEO best practices.

PASSED AUDITS (8) Hide

- Has a `<meta name="viewport">` tag with `width` or `initial-scale`

A `<meta name="viewport">` not only optimizes your app for mobile screen sizes, but also prevents a 300 millisecond delay to user input. Learn more. TBT

- Document has a `<title>` element

The title gives screen reader users an overview of the page, and search engine users rely on it heavily to determine if a page is relevant to their search. Learn more.

- Document has a meta description

Meta descriptions may be included in search results to concisely summarize page content. Learn more.

- Page has successful HTTP status code

Pages with unsuccessful HTTP status codes may not be indexed properly. Learn more.

Links have descriptive text

Descriptive link text helps search engines understand your content. Learn more.

Page isn't blocked from indexing

Search engines are unable to include your pages in search results if they don't have permission to crawl them. Learn more.

Document has a valid `hreflang`

hreflang links tell search engines what version of a page they should list in search results for a given language or region. Learn more.

Document avoids plugins

Search engines can't index plugin content, and many devices restrict plugins or don't support them. Learn more.

NOT APPLICABLE (4) Hide

Image elements have `[alt]` attributes

Informative elements should aim for short, descriptive alternate text. Decorative elements can be ignored with an empty alt attribute. Learn more.

Document has a valid `rel=canonical`

Canonical links suggest which URL to show in search results. Learn more.

Document uses legible font sizes

Font sizes less than 12px are too small to be legible and require mobile visitors to "pinch to zoom" in order to read. Strive to have >60% of page text ≥12px. Learn more.

Tap targets are sized appropriately

Interactive elements like buttons and links should be large enough (48x48px), and have enough space around them, to be easy enough to tap without overlapping onto other elements. Learn more.

PWA

These checks validate the aspects of a Progressive Web App. Learn more.

INSTALLABLE

▲ Web app manifest or service worker do not meet the installability requirements — 1 reason

Service worker is the technology that enables your app to use many Progressive Web App features, such as offline, add to homescreen, and push notifications. With proper service worker and manifest implementations, browsers can proactively prompt users to add your app to their homescreen, which can lead to higher engagement. Learn more.

Failure reason

Page has no manifest <link> URL

PWA OPTIMIZED

▲ Does not register a service worker that controls page and `start_url`

The service worker is the technology that enables your app to use many Progressive Web App features, such as offline, add to homescreen, and push notifications. Learn more.

▲ Is not configured for a custom splash screen Failures: No manifest was fetched.

A themed splash screen ensures a high-quality experience when users launch your app from their homescreens. Learn more.

▲ Does not set a theme color for the address bar.
Failures: No manifest was fetched, No `<meta name="theme-color">` tag found.

The browser address bar can be themed to match your site. Learn more.

○ Content is sized correctly for the viewport

If the width of your app's content doesn't match the width of the viewport, your app might not be optimized for mobile screens. Learn more.

university of groningen / faculty of science and engineering / computing science

Has a `<meta name="viewport">` tag with `width` or `initial-scale`

A `<meta name="viewport">` not only optimizes your app for mobile screen sizes, but also prevents a 300 millisecond delay to user input. Learn more. TBT

▲ Does not provide a valid `apple-touch-icon`

For ideal appearance on iOS when users add a progressive web app to the home screen, define an `apple-touch-icon`. It must point to a non-transparent 192px (or 180px) square PNG. Learn More.

▲ Manifest doesn't have a maskable icon No manifest was fetched

A maskable icon ensures that the image fills the entire shape without being letterboxed when installing the app on a device. Learn more.

ADDITIONAL ITEMS TO MANUALLY CHECK (3) Hide

○ Site works cross-browser

To reach the most number of users, sites should work across every major browser. Learn more.

○ Page transitions don't feel like they block on the network

Transitions should feel snappy as you tap around, even on a slow network. This experience is key to a user's perception of performance. Learn more.

○ Each page has a URL

Ensure individual pages are deep linkable via URL and that URLs are unique for the purpose of shareability on social media. Learn more.

These checks are required by the baseline PWA Checklist but are not automatically checked by Lighthouse. They do not affect your score but it's important that you verify them manually.

Captured at Aug 18, 2022, 6:58 PM GMT+2
Initial page load
Emulated Desktop with Lighthouse 9.6.1
Custom throttling
Single page load
Using Chromium 104.0.0.0 with devtools

Generated by **Lighthouse** 9.6.1 | File an issue