

TALLINN UNIVERSITY OF TECHNOLOGY
School of Information Technologies

Alina Kogai 179247IACB

Browsers and their use in smart devices

Bachelor's thesis

Supervisor: Vladimir Viies
Associate Professor

Tallinn 2020

TALLINNA TEHNIKAÜLIKOOL
Infotehnoloogia teaduskond

Alina Kogai 179247IACB

Brauserid ja nende kasutamine nutiseadmetes

Bakalaureusetöö

Juhendaja: Vladimir Viies
Dotsent

Tallinn 2020

Author's declaration of originality

I hereby certify that I am the sole author of this thesis. All the used materials, references to the literature and the work of others have been referred to. This thesis has not been presented for examination anywhere else.

Author: Alina Kogai

30.11.2020

BAKALAUREUSETÖÖ ÜLESANDEPÜSTITUS

Kuupäev: 23.09.2020

Üliõpilase ees- ja perekonnanimi: Alina Kogai

Üliõpilaskood: 179247IACB

Lõputöö teema: Brauserid ja nende kasutamine nutiseadmetes

Juhendaja: Vladimir Viies

Kaasjuhendaja:

Lahendatavad küsimused ning lähtetingimused:

Populaarsemate brauserite analüüs. Analüüs arvestada: mälu kasutus, kiirus turvalisus ja privaatsus, brauserite lisad. Valja toodate brauseri valiku kriteeriumid ja soovitused.

Lõpetaja allkiri
(*digitaalselt allkirjastatud*)

Abstract

The aim of this bachelor's thesis is to give recommendations on which web browser is best suited for different user groups on different platforms.

The thesis presents a methodology for evaluating browsers which are available on all platforms based on certain criteria. Tests on PC, mobile and tablet were performed for methodology demonstration. To evaluate the importance of the criteria a survey was conducted. The results are used to make recommendations to Internet user groups on the selection of the most suitable browser for different platforms.

This thesis is written in English and is 43 pages long, including 5 chapters, 20 figures and 18 tables.

Annotatsioon

Brauserid ja nende kasutamine nutiseadmetes

Selle bakalaureuse töö eesmärk on anda nõuandeid selle kohta, milline veebibrauser erinevatel platvormidel sobib erinevate kasutajagruppide jaoks kõige parem.

Selles töös on esitatud brauserite hindamise metoodika erinevate kriteeriumide alusel. Metoodika demonstreerimiseks olid läbiviidud testid. Kriteeriumite olulisuse hindamiseks oli läbiviidud uuring. Lõpptulemuste põhjal on tehtud erinevatele kasutajagruppidele soovitusi, kuidas valida sobivaim brauser erinevate platvormide jaoks.

Lõputöö on kirjutatud inglise keeles ning sisaldab teksti 43 leheküljel, 5 peatükki, 20 joonist, 18 tabelit.

List of abbreviations and terms

HTML	Hypertext Markup Language
HTTP	Hypertext Transfer Protocol
OS	Operating system
PC	Personal Computer
VPN	Virtual Private Network

Table of contents

1 Introduction	11
2 Browsers	12
2.1 Platforms and browsers	12
2.2 Most used browsers	13
2.3 Criteria of browser evaluation	15
3 Browser testing	17
3.1 Devices for testing	17
3.2 Testing on the PC	18
3.3 Testing on mobile	23
3.4 Testing on a tablet.....	27
4 Browser evaluation method	31
4.1 Survey to obtain weight coefficient.....	31
4.2 Browser evaluation results.....	33
4.3 Recommendations for choosing a browser on different platforms.....	37
5 Summary.....	39
References	40
Appendix 1 – Non-exclusive licence for reproduction and publication of a graduation thesis	42
Appendix 2 – Survey	43

List of figures

Figure 1. PC, Mobile & Tablet Browser Market Share Worldwide.....	14
Figure 2. PC JetStream2 test results	18
Figure 3. PC MotionMark test results	18
Figure 4. PC Speedometer test results	19
Figure 5. PC browsers memory usage	19
Figure 6. PC browsers memory usage with three extensions	20
Figure 7. Difference between 0 min and 10 min of browsers memory usage on PC	21
Figure 8. Mobile JetStream2 test results	23
Figure 9. Mobile MotionMark test results.....	23
Figure 10. Mobile Speedometer test results	24
Figure 11. Mobile browsers memory usage	24
Figure 12. Difference between 0 min and 10 min of browsers memory usage on mobile	25
Figure 13. Tablet JetStream2 test results.....	27
Figure 14. Tablet MotionMark test results	27
Figure 15. Tablet Speedometer test results.....	28
Figure 16. Tablet browsers memory usage.....	28
Figure 17. Difference between 0 min and 10 min of browsers memory usage on mobile	29
Figure 18. Browsers for regular user	37
Figure 19. Browsers for student	37
Figure 20. Browsers for advanced user	38

List of tables

Table 1. Compatibility of popular browsers, platforms and operating systems.....	12
Table 2. Models of used devices, versions of the operating system and browsers	17
Table 3. PC security and privacy	22
Table 4. PC usability	22
Table 5. Mobile security and privacy	25
Table 6. Mobile usability	26
Table 7. Tablet security and privacy	29
Table 8. Tablet usability	30
Table 9. The number of respondents who voted for a certain criterion.....	32
Table 10. Rules for evaluating an internet survey	32
Table 11. Weight coefficient for each group.....	32
Table 12. Rules for evaluating of JetStream2, MotionMark and Speedometer browsers tests	33
Table 13. Rules for evaluating browser memory usage	33
Table 14. Rules for evaluating usability, security and privacy of browsers.....	34
Table 15. Browser evaluation results	34
Table 16. Browsers evaluation results for regular users.....	35
Table 17. Browsers evaluation results for students	35
Table 18. Browsers evaluation results for advance users	36

1 Introduction

The aim of this bachelor's thesis is to give recommendations on which web browser is best suited for different user groups (regular user, student and advanced user) on different platforms (PC, mobile and tablet).

The points that will be explored in the thesis: browser memory usage, browser speed, browser security and privacy, criteria and recommendations for choosing browsers.

A definition of what a web browser is and a brief description of the most popular web browsers will be given. Criteria for evaluating web browsers will be listed as well.

Tests to evaluate browsers by criteria will be conducted.

A method for evaluating web browsers will be described and demonstrated. Recommendations for different user groups on different platforms will be given at the end of the work.

This bachelor's work is divided into five parts.

The first part introduces the topic of the thesis, its goals and highlights which problems will be solved. The second part provides an overview of the information about web browsers. The third part conducts test and results overview. The fourth part describes and demonstrates browser evaluation method. The fifth part presents the main goal of the thesis and provides answers to problems.

2 Browsers

In our time, it is difficult to imagine life without the Internet. It does not matter what device you use; one thing remains the same. In order to use the Internet, you need a web browser.

What is a web browser? In the presentation by Maira Zhumagalieva [10] the concept of a web browser was described as " A special program designed for viewing websites. This happens with the help of HTTP requests to the server and receiving data from it, which are processed according to special approved standards and thus a web page is formed".

2.1 Platforms and browsers

The following table shows the compatibility of the most popular browsers and operating systems:

Table 1. Compatibility of popular browsers, platforms and operating systems.

	PC		Tablet		Mobile	
	Windows	Mac	Android	iOS	Android	iOS
Google Chrome	+	+	+	+	+	+
Safari	-	+	-	+	-	+
Mozilla Firefox	+	+	+	+	+	+
Samsung Internet	-	-	+	-	+	-
Microsoft Edge	+	+	+	+	+	+
Opera	+	+	+	+	+	+

For the research only those browsers that are available on all operating systems and platforms were selected. These are Google Chrome, Mozilla Firefox, Microsoft Edge and Opera browsers.

Safari browser is available only on Apple devices with Mac or iOS operating systems. It cannot be used on Windows or Android. Samsung Internet is available only on Android operating systems.

The research will not include a comparison of browser performance on different operating systems due to the lack of Apple devices for testing.

2.2 Most used browsers

Below is a brief description of the most used browsers.

Google Chrome

The first version of the Chrome browser was released on September 2, 2008 [4]. In the beginning, Chrome used the WebKit rendering engine to render web pages. April 2013, they split the WebCore component to create their Blink layout engine [5]. Chrome was released for Apple and Android in 2012 [6].

Safari

Safari is an Apple web browser. It was first released for the desktop in 2003 on Mac OS X [11]. The mobile version was released in 2007 along with the first iPhone [12]. Safari includes the WebKit2 and Nitro engines [13].

Mozilla Firefox

Mozilla Firefox was developed by the Mozilla Foundation and its subsidiary, the Mozilla Corporation in 2002. Firefox is based on the open-source Gecko layout engine developed by Mozilla. Firefox for mobile was first released for Android in 2011 and iOS in 2015 [8][9]. [8][9].

Samsung Internet

Samsung Internet is a mobile web browser for devices developed by Samsung. It is based on the open-source Chromium project. It has been available for download from Google Play since 2015 [14].

Microsoft Edge

It was first released for Windows 10 in 2015, then for Android and iOS in 2017 [1]. Edge was originally built by Microsoft using its own proprietary EdgeHTML browser engine and their Chakra JavaScript engine, now the version is called Microsoft Edge Legacy [2]. However, Microsoft later decided to opt for the popular open-source Chromium engine [3].

Opera

Opera was developed by the telecommunications company Telenor by Jon Stephenson von Techner and Geir Ivarsoy in 1994. In 1995, Jon Stephenson von Techner and Geir Ivarsoy created Opera Software and released the first version of the browser [7]. Opera is a Chromium-based browser using the Blink engine. Also, Opera has three mobile versions called Opera mobile, Opera mini and Opera Touch.

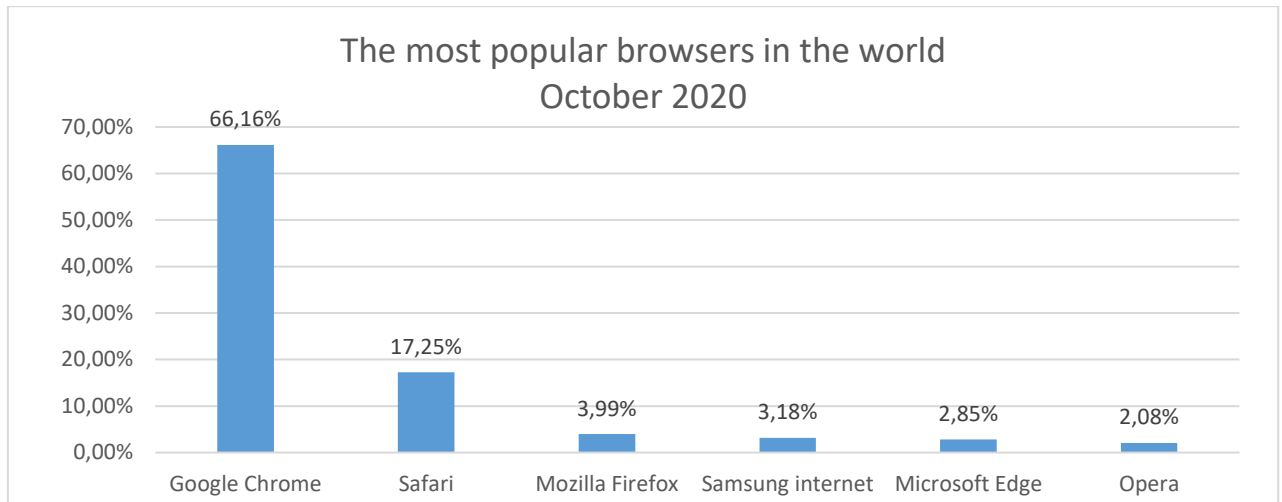


Figure 1. PC, Mobile & Tablet Browser Market Share Worldwide

Figure 1 shows that Google Chrome is the most popular browser [17]. There are many reasons for this. The main reasons are that Google Chrome is the default browser for devices with the Android operating system, as well as the great popularity of the Google search engine and other Google resources, such as Gmail, Google Maps, Google Translator, etc.

The second most popular browser is Safari. The reason for this is that Safari is the default browser for all Apple devices.

Browsers like Mozilla Firefox, Samsung Internet, Microsoft Edge and Opera are used much less than Chrome and Safari, from 2% - 4% per cent of the total.

2.3 Criteria of browser evaluation

In criteria choosing I was based on the internet article and website: «*The Best Browsers, Compared with Data: Chrome, Firefox, Edge, Opera, Safari, and Vivaldi*» [19] by Benjamin Brandall, 2017 and «*Which browser is the fastest in 2020*» [20] from remontcompania.ru website.

In Benjamin Brandall's article author chooses the next criteria for browser evaluation:

- Speed
- Range of extensions
- Memory usage
- Security and privacy
- Usability

I decided not to include a «range of extensions» criterion for this thesis, because on some platforms browsers do not have extensions.

In remontcompania.ru website they evaluated the criterion of speed according to three criteria:

- JetStream2 test
- MotionMark test
- Speedometer test

JetStream2 combines a variety of JavaScript and Web Assembly benchmarks, covering a variety of advanced workloads and programming techniques, and reports a single score that balances them using a geometric mean [16].

MotionMark is a graphics benchmark that measures a browser's capability to animate complex scenes at a target frame rate [17].

Speedometer is a browser benchmark that measures the responsiveness of Web applications [18].

Browser **memory usage** is important because the amount of memory that a browser can use on a device is strictly limited by the amount of memory on that device. In some cases, the amount of memory may not be enough for the stable operation of the browser.

Security and privacy of browser use are important criteria, since browsers store a lot of personal user data, such as addresses, passwords, bank account numbers, etc.

Usability is important because different browsers have different internal functionality. Some functions that may be important to the user may not be available in one browser or another, so the user can choose another browser.

Selected criteria:

1. JetStream2 test
2. MotionMark test
3. Speedometer test
4. Memory usage
5. Security and privacy
6. Usability

3 Browser testing

This part will give an overview of the devices that are used for testing and will show the test results with an overview.

All tests were carried out in the same conditions, namely, nothing but browsers were launched on the devices during testing.

3.1 Devices for testing

For the tests, devices that were released over the past 5 years were selected. They were chosen because modern browsers are made for modern devices.

Table 2 shows the models of devices used during testing, versions of operating systems and browsers. Operating systems and browsers have been updated to the latest version available.

Table 2. Models of used devices, versions of the operating system and browsers

			Browser and version			
	Model	OS	Google Chrome	Mozilla Firefox	Opera	Microsoft Edge
PC	Lenovo IdeaPad Y700	Windows 10	86.0	82.0	72.0	86.0
Mobile	Xiaomi mi 9T	Android 10	86.0	82.1	60.3	45.09
Tablet	Lenovo TB2-X30L	Android 7	86.0	82.1	60.3	45.10

3.2 Testing on the PC

JetStream2 test

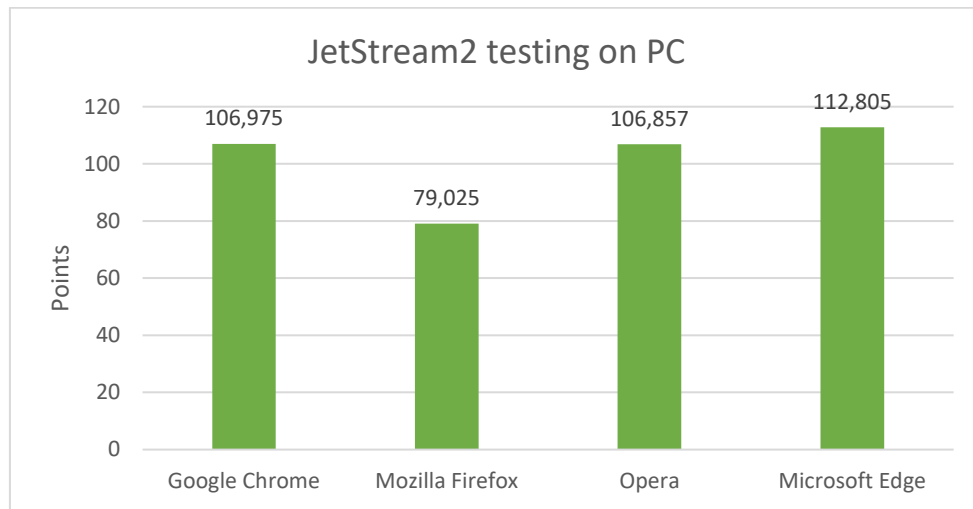


Figure 2. PC JetStream2 test results

The test results (Figure 2) show that on the PC the Microsoft Edge browser performed best on the JetStream2 test. Google Chrome and Opera browsers are on the same level. Mozilla Firefox browser is in the last place.

MotionMark test

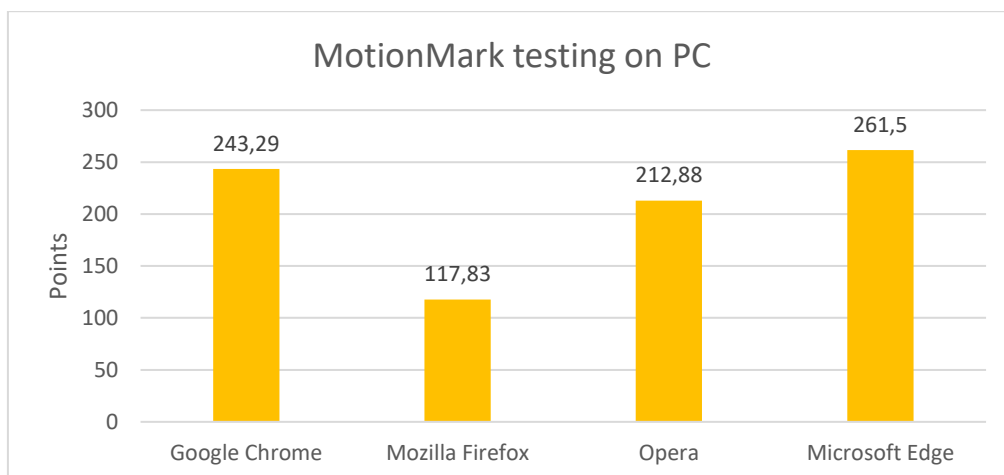


Figure 3. PC MotionMark test results

The test results (Figure 3) show that on PC the Microsoft Edge browser performed best on the MotionMark test. Google Chrome browser is in second place. Opera browser is in third place. Mozilla Firefox browser is in the last place.

Speedometer test

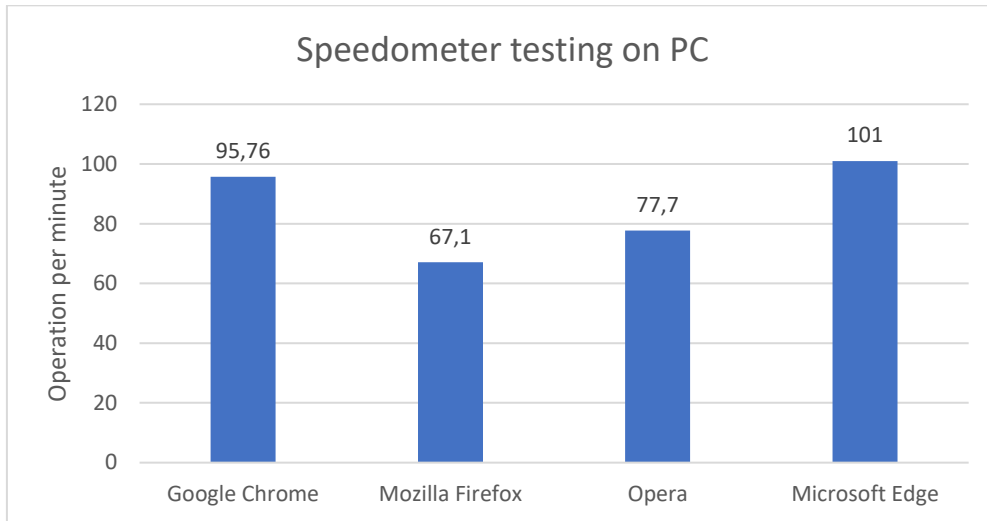


Figure 4. PC Speedometer test results

The test results (Figure 4) show that on PC Microsoft Edge browser performed best on the Speedometer test. Google Chrome browser is in second place. Opera browser is in third place. Mozilla Firefox browser is in the last place.

Memory usage

To test memory usage in each of the browsers 5 tabs were launched: google.com, taltech.ee, bbc.com, facebook.com, youtube.com.

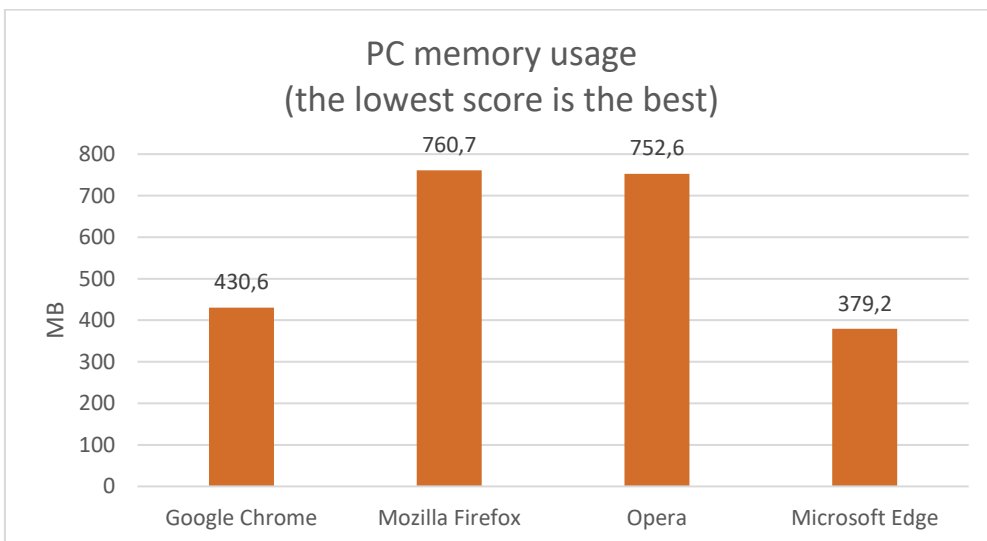


Figure 5. PC browser memory usage

The test results (Figure 5) show that Microsoft Edge browser uses the least amount of memory on PC. In second place in terms of memory usage is Google Chrome browser. Opera and Mozilla Firefox browsers show themselves about the same using a large amount of memory.

For purity of testing, browsers on PC were also tested with the three most used extensions which are available on all tested browsers: Google Translate, Enhancer for YouTube, Adblock Plus.

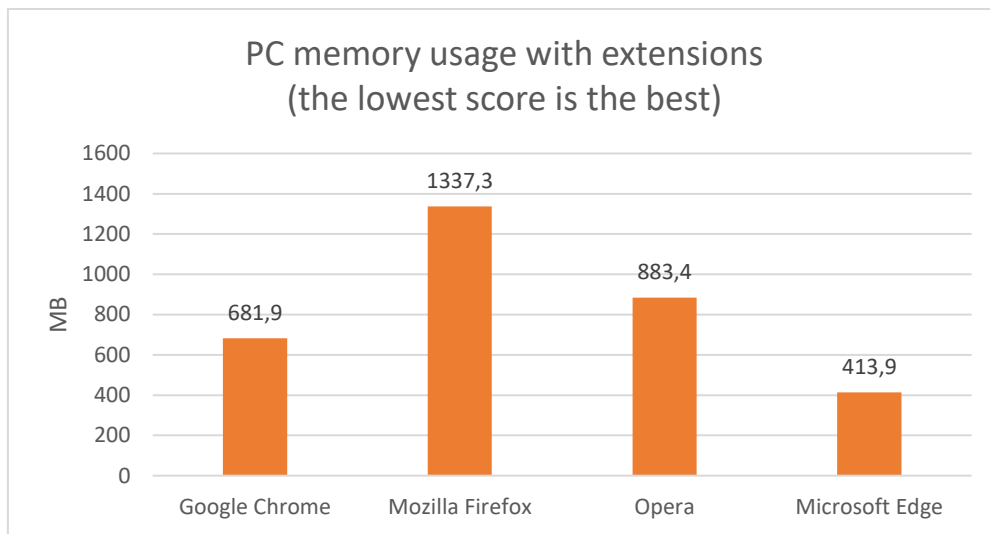


Figure 6. PC browser memory usage with three extensions

The test results (Figure 6) show that browsers with installed extensions use more memory than browsers without extensions. However, extensions, not browsers, are responsible for such results.

Due to this, the evaluation of the performance of browsers will be based on the performance of browsers without extensions.

Also, to evaluate the memory usage of the browser the difference in memory usage after 10 minutes of using the browser was measured.

Figure 7 shows how much memory usage increases after 10 minutes of using the browser.

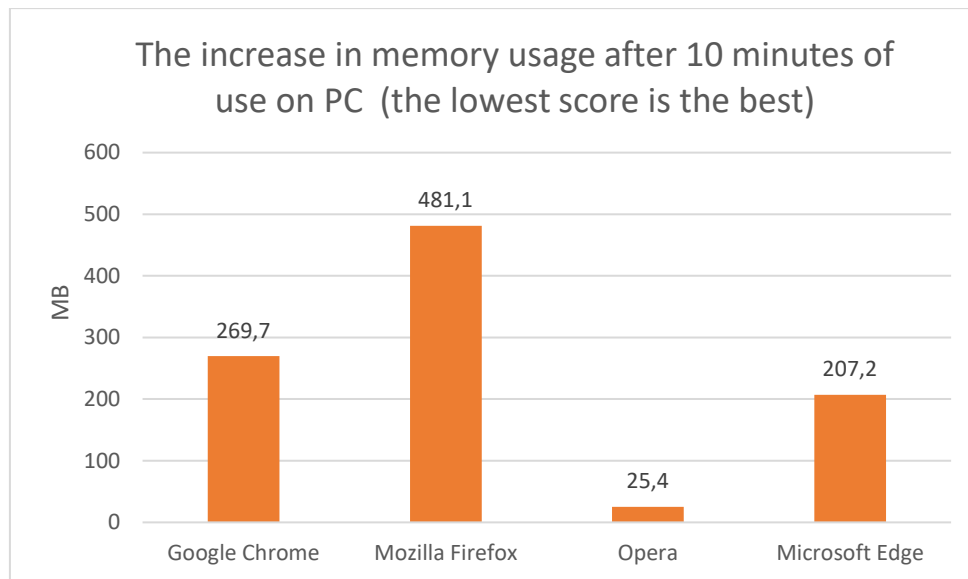


Figure 7. Difference between 0 min and 10 min of browser memory usage on PC

The test results (Figure 7) show that Opera browser uses the least amount of memory after 10 minutes of work on the PC. Microsoft Edge browser takes the second place. Google Chrome – the third place. Mozilla Firefox browser takes the last place.

Security and privacy

For the evaluation of the security and privacy of browsers the features that each browser includes were analyzed. The analysis included only those functions that the browser includes by default, extensions were not considered.

When using Block Pop-ups, the browser prevents additional windows from opening automatically. Do Not Track is a feature that prohibits websites from tracking user activity in order to provide personalized ads. Disabling cookies prevents the browser from storing cookies on the device. In private browsing, the browser does not remember visited web pages, passwords, searches, downloads, cache contents and cookies. Clear browsing data deletes all collected browsing data. Crypto Mining Blocker blocks crypto mining websites and embedded scripts for mining on sites. Fingerprint blocker protects fingerprint data.

Table 3. PC security and privacy

	Google Chrome	Mozilla Firefox	Opera	Microsoft Edge
Block pop-ups	+	+	+	+
Do Not Track	+	+	+	+
Enable/disable cookies	+	+	+	+
Private Browsing	+	+	+	+
Clear browsing data	+	+	+	+
Crypto Mining Blocker	-	+	-	-
Fingerprint blocker	-	+	-	-
Score:	5	7	5	5

Table 3 shows that all browsers have block pop-ups, do not track, enable/disable cookies, private browsing, clear browsing data features. Mozilla Firefox provides most of the available features.

Usability

To compare the usability of browsers the presence of different useful browser features was analyzed.

Table 4. PC usability

	Google Chrome	Mozilla Firefox	Opera	Microsoft Edge
Built-in AdBlock	+	+	+	-
Built-in VPN	-	-	+	-
Customization	+	+	+	+
RAM control function	-	-	-	-
Change search engine	+	+	+	+
Home page management	+	-	+	+
Synchronization	+	+	+	+
Bookmark management	+	+	+	+
Extension Store	+	+	+	+
Website notification	+	+	+	+
Save passwords	+	+	+	+
Form autocomplete	+	+	+	+
Score:	10	9	11	9

The comparison results show that the Opera browser has the most useful features such as built-in AdBlock and VPN. The second place goes to Google Chrome browser. Microsoft Edge and Mozilla Firefox browsers take the third place.

3.3 Testing on mobile

JetStream2 test

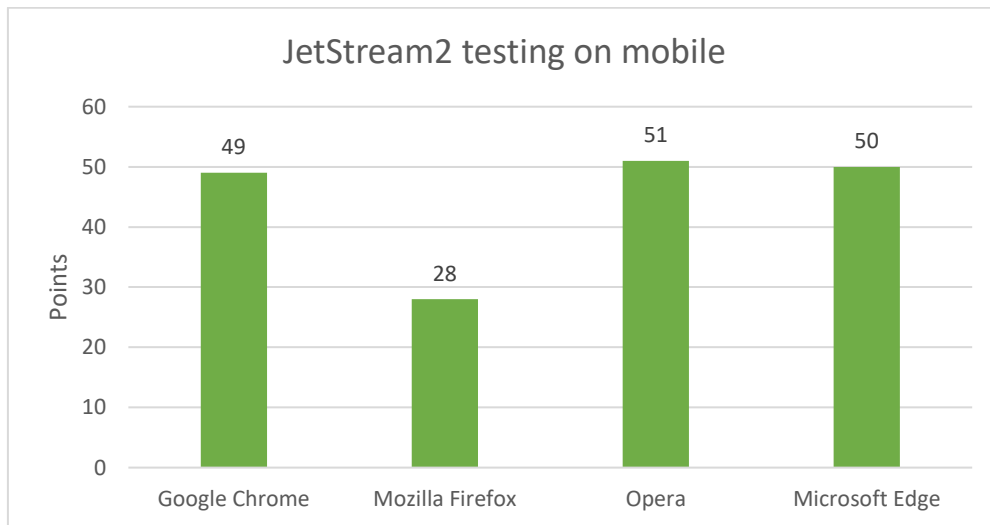


Figure 8. Mobile JetStream2 test results

The test results show that on mobile Opera, Microsoft Edge and Google Chrome browsers are on the same level in the JetStream2 test. Mozilla Firefox browser is in the last place.

MotionMark test

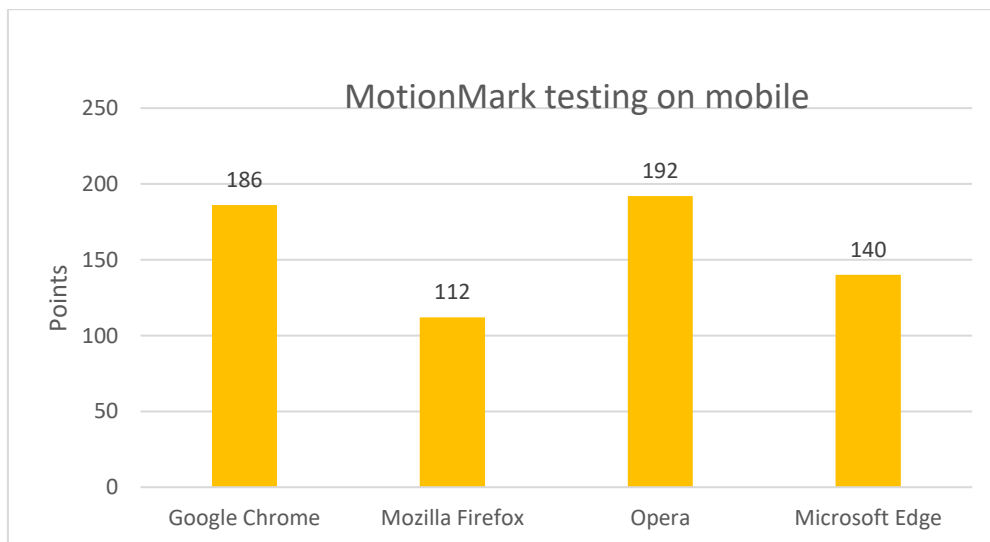


Figure 9. Mobile MotionMark test results

The test results show that on mobile Opera browser performed best during the MotionMark test. Google Chrome browser takes the second place. Microsoft Edge browser is in the third place. Mozilla Firefox browser is in the last place.

Speedometer test

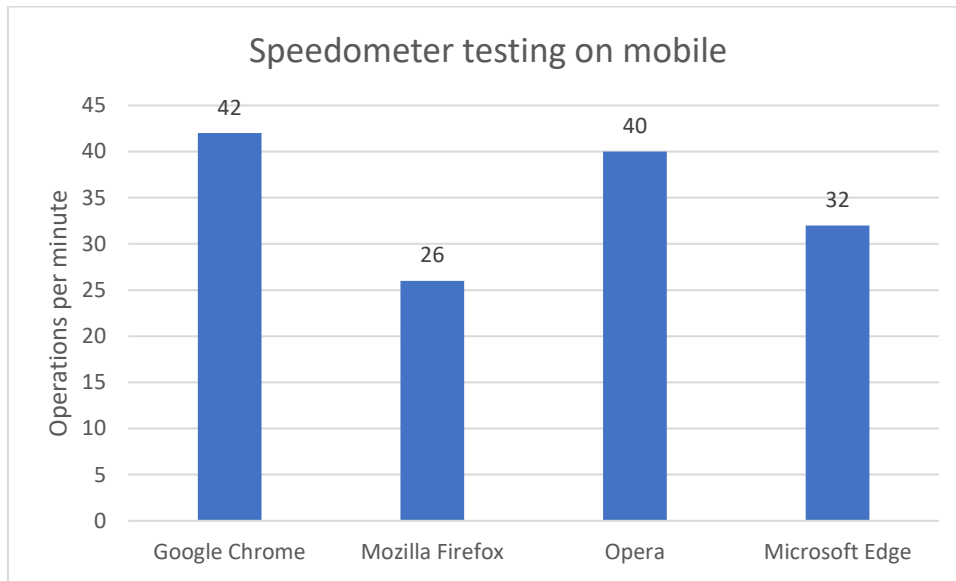


Figure 10. Mobile Speedometer test results

The test results show that on PC Google Chrome browser performed best on the Speedometer test. Opera browser is in the second place. Microsoft Edge browser is in the third place. Mozilla Firefox browser is in the last place.

Memory usage

To test memory usage the same method as with PC was used.

Namely, in each of the browsers 5 tabs were launched: google.com, taltech.ee, bbc.com, facebook.com, youtube.com.

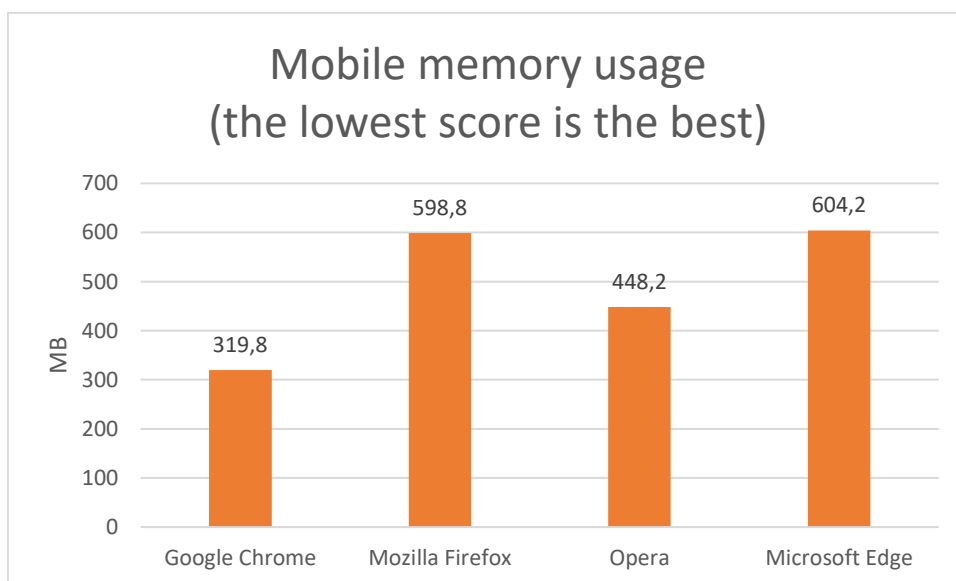


Figure 11. Mobile browser memory usage

The test results show that Google Chrome browser uses the least amount of memory on PC. In the second place in terms of memory usage is Opera browser. Mozilla Firefox and Microsoft Edge browsers show themselves about the same therefore they are in the last place.

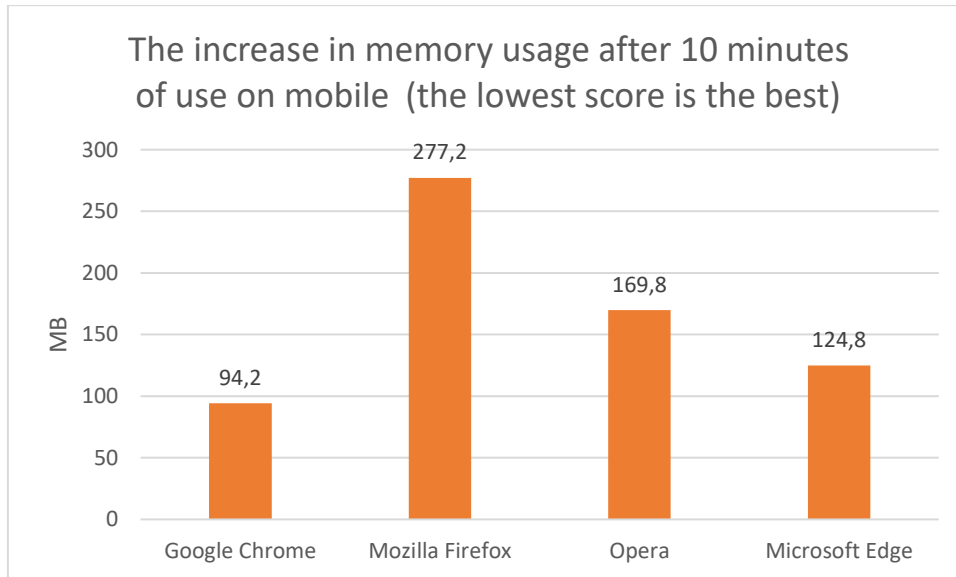


Figure 12. Difference between 0 min and 10 min of browser memory usage on mobile

The test results show that Google Chrome browser uses the least amount of memory after 10 minutes of work on mobile. Microsoft Edge browser is in the second place. Opera browser is in the third place. Mozilla Firefox browser is in the last place.

Security and privacy

Table 5. Mobile security and privacy

	Google Chrome	Mozilla Firefox	Opera	Microsoft Edge
Block pop-ups	+	+	+	+
Do Not Track	+	+	-	+
Enable/disable cookies	+	+	+	+
Private Browsing	+	+	+	+
Clear browsing data	+	+	+	+
Crypto Mining Blocker	-	+	-	-
Fingerprint blocker	-	+	-	-
Score:	5	7	4	5

All browsers have block pop-ups, enable/disable cookies, private browsing, clear browsing data features. Mozilla Firefox provides most of the available features.

Usability

Table 6. Mobile usability

	Google Chrome	Mozilla Firefox	Opera	Microsoft Edge
Built-in AdBlock	-	-	+	-
Built-in VPN	-	-	+	-
Customization	+	+	+	+
RAM control function	-	-	-	-
Change search engine	+	+	+	+
Home page management	+	-	+	+
Synchronization	+	+	+	+
Bookmark management	+	+	+	+
Extension Store	+	+	-	-
Website notification	+	+	+	+
Save passwords	+	+	+	+
Form autocomplete	+	+	+	+
Score:	9	8	10	8

The comparison results show that the Opera browser has the most useful features such as built-in AdBlock and VPN. In the second place is Google Chrome browser. In the third place are Microsoft Edge and Mozilla Firefox browsers.

3.4 Testing on a tablet

JetStream2 test

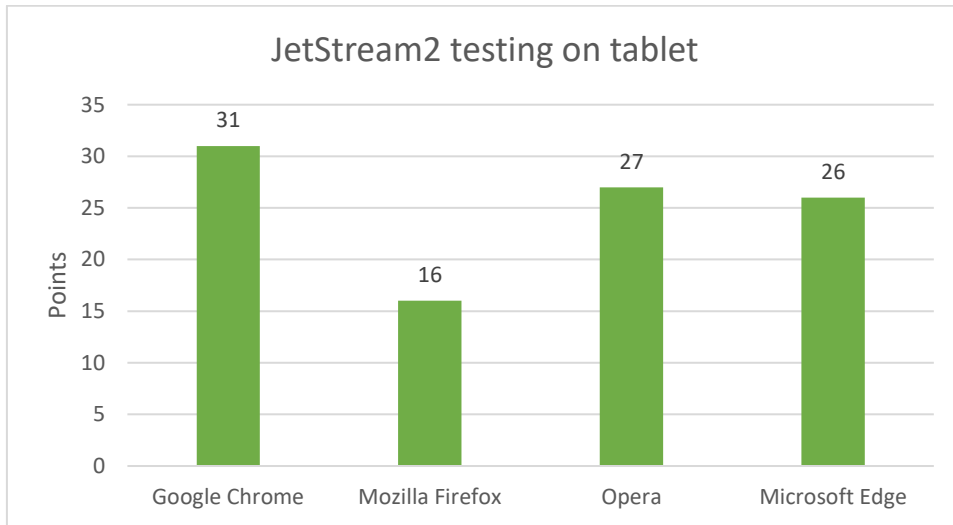


Figure 13. Tablet JetStream2 test results

The test results show that on tablet Google Chrome browser performed best during the JetStream2 test. Opera browser is in the second place. Microsoft Edge browser is in the third place. Mozilla Firefox browser is in the last place.

MotionMark test

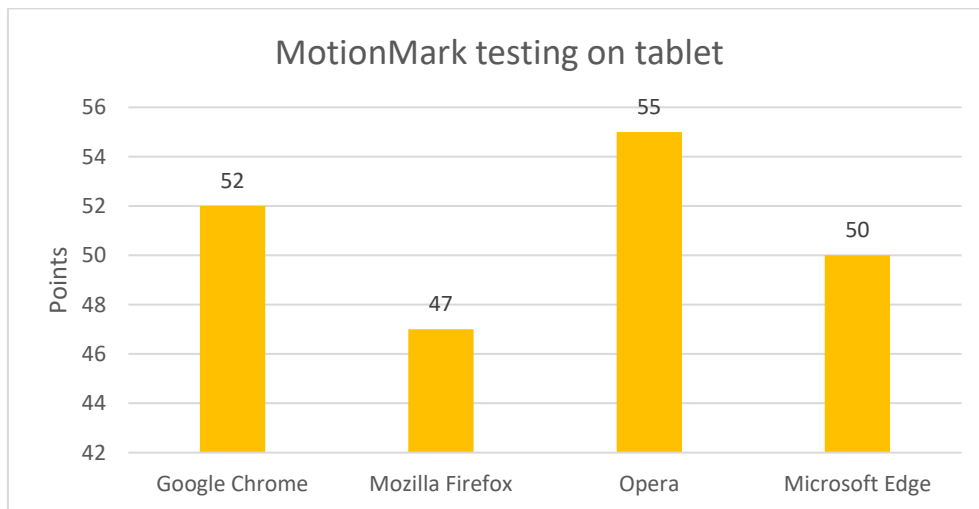


Figure 14. Tablet MotionMark test results

The test results show that on tablet Opera browser performed best during the MotionMark test. Google Chrome browser is in the second place. Microsoft Edge browser is in the third place. Mozilla Firefox browser is in the last place.

Speedometer test

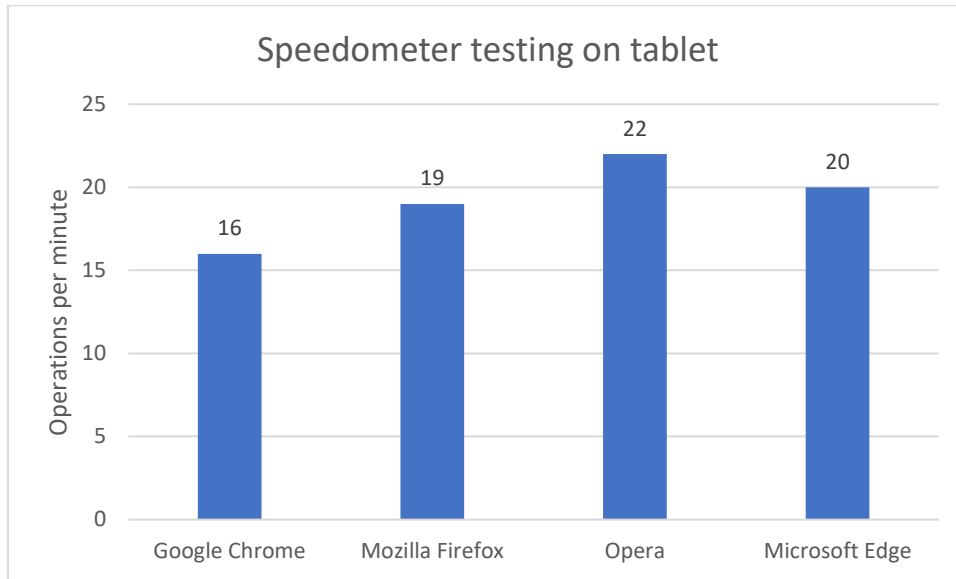


Figure 15. Tablet Speedometer test results

The test results show that on tablet Opera browser performed best during the Speedometer test. Microsoft Edge browser is in the second place. The Mozilla Firefox browser is in the third place. Google Chrome browser is in the last place.

Memory usage

To test memory usage the same method as with PC and mobile was used.

Namely, in each of the browsers 5 tabs were launched: google.com, taltech.ee, bbc.com, facebook.com, youtube.com.

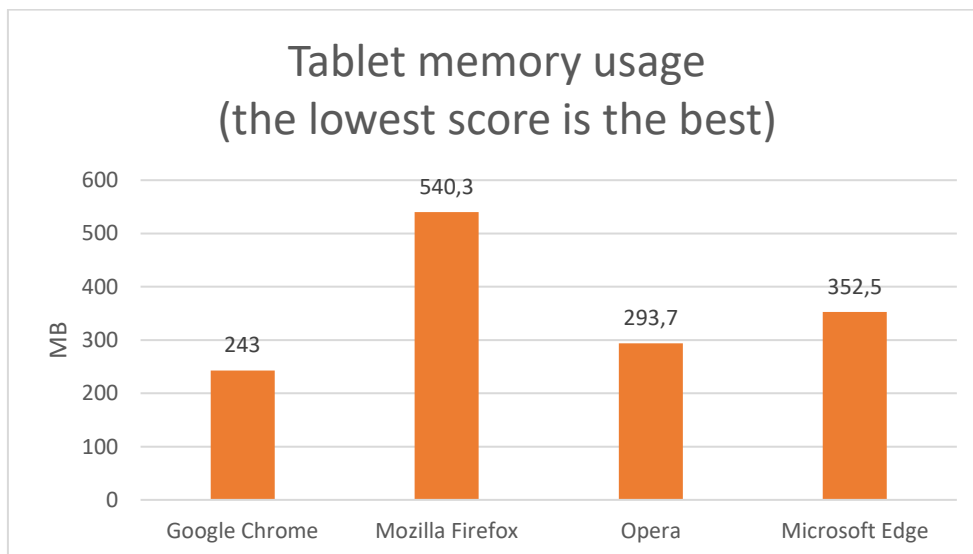


Figure 16. Tablet browser memory usage

The test results show that Google Chrome browser uses the least amount of memory on tablet. In the second place in terms of memory usage is Opera browser. Microsoft Edge browser is in the third place and Mozilla Firefox is in the last place in memory usage.

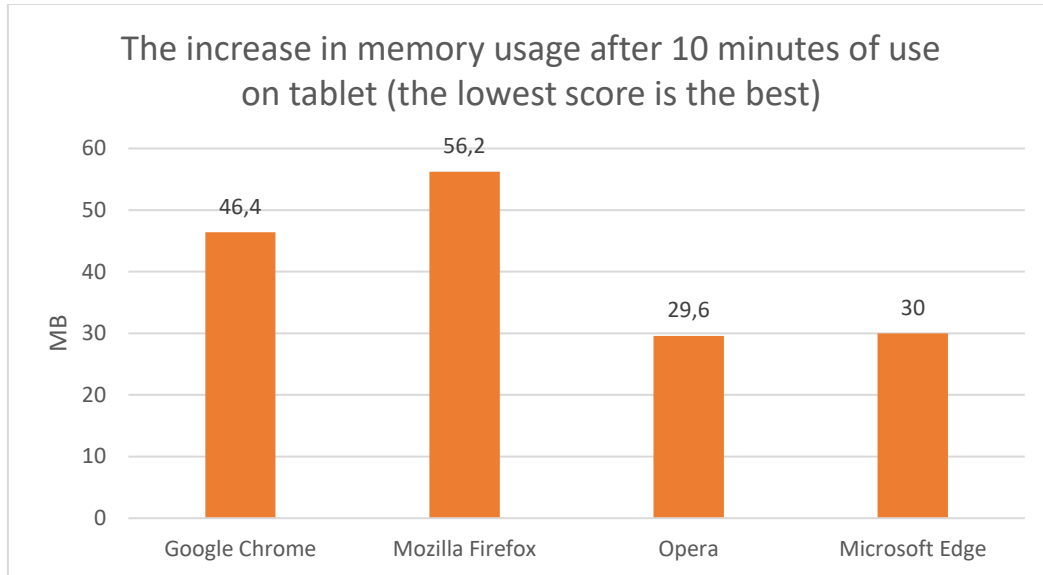


Figure 17. Difference between 0 min and 10 min of browser memory usage on mobile

The test results show that the Opera browser uses the least amount of memory after 10 minutes of work on tablet. Microsoft Edge browser is in the second place. Google Chrome browser is in the third place. Mozilla Firefox browser is in the last place.

Security and privacy

Table 7. Tablet security and privacy

	Google Chrome	Mozilla Firefox	Opera	Microsoft Edge
Block pop-ups	+	+	+	+
Do Not Track	+	+	-	+
Enable/disable cookies	+	+	+	+
Private Browsing	+	+	+	+
Clear browsing data	+	+	+	+
Crypto Mining Blocker	-	+	-	-
Fingerprint blocker	-	+	-	-
Score:	5	7	4	5

All browsers have block pop-ups, enable/disable cookies, private browsing, clear browsing data features. Mozilla Firefox provides most of the available features.

Usability

Table 8. Tablet usability

	Google Chrome	Mozilla Firefox	Opera	Microsoft Edge
Built-in AdBlock	-	-	+	-
Built-in VPN	-	-	+	-
Customization	+	+	+	+
RAM control function	-	-	-	-
Change search engine	+	+	+	+
Home page management	+	-	+	+
Synchronization	+	+	+	+
Bookmark management	+	+	+	+
Extension Store	+	+	-	-
Website notification	+	+	+	+
Save passwords	+	+	+	+
Form autocomplete	+	+	+	+
Score:	9	8	10	8

The comparison results show that the Opera browser has the most useful features such as built-in AdBlock and VPN. In the second place is the Google Chrome browser. In the third place are Microsoft Edge and Mozilla Firefox browsers.

4 Browser evaluation method

Following the evaluation rules which will be shown in paragraph 4.2, browsers are assigned individual grades for each of the criteria which were shown in paragraph 2.3, after what the points are summed up and recorded in summary tables (Table 16 - 18) for each user group (regular user, student, and advanced user) with the results for PC, mobile and tablet.

For the final evaluation and recommendation of the most suitable browser for all user groups the following Formula 1 is used:

$$f(x) = \sum_{i=1}^n k_i a_i$$

where k_i – weight coefficient and a_i – assessment.

4.1 Survey to obtain weight coefficient

To obtain the weight coefficient the results obtained by the survey (Appendix 2) were used.

The survey was conducted using Twitter and Facebook social networks. The number of respondents who completed the survey is 203.

All respondents could classify themselves as one or another group of Internet users (regular user, student or advanced user). According to the survey 57 people marked themselves as a regular user, 72 people marked themselves as a student, and 74 people marked themselves as an advanced user.

Also, each respondent could choose which criteria were most important to them during working with a web browser (up to three answers). The criteria meet the criteria given in paragraph 2.3.

Table 9. The number of respondents who voted for a certain criterion.

	Regular user	Student	Advanced user
JetStream2	22	23	35
MotionMark	21	9	4
Speedometer	39	56	52
Memory usage	14	16	24
Security and privacy	34	51	43
Usability	35	48	51

Table 9 shows the number of respondents who voted for a certain criterion in the survey. The following will describe the rules for evaluating the survey (Appendix 2).

Table 10. Rules for evaluating an internet survey

Points	Regular user	Student	Advanced user
1	14,00 - 18,99	9,00 - 18,39	4,00 - 13,60
2	19,00 - 23,99	18,40 - 27,79	13,61 - 23,19
3	24,00 - 28,99	27,80 - 37,19	23,20 - 32,79
4	29,00 - 33,99	37,20 - 46,59	32,80 - 42,39
5	34,00 - 39,00	46,60 - 56	42,40 - 52,00

Table 10 shows the evaluation rules based on the survey results. The rule is that the smallest value is subtracted from the largest value, and the difference is divided by 5 equal steps. For example, for a regular user, the lowest number of votes for any criterion was 14, the highest – 39. The difference between these two indicators was divided into 5 equal steps.

Table 11. Weight coefficient for each group

	Regular user	Student	Advanced user
JetStream2	2	2	4
MotionMark	2	1	1
Speedometer	5	5	5
Memory usage	1	1	3
Security and privacy	5	5	5
Usability	5	5	5

Table 11 shows the weight coefficients of each criterion for each surveyed group using the rules for evaluating the internet survey (Table 10). Criteria that receive many votes receive more points; those that receive few votes receive fewer points.

4.2 Browser evaluation results

According to the criteria presented in paragraph 2.3 the rules for evaluating browsers based on the results obtained in paragraphs 3.2 – 3.4 are presented below.

Table 12. Rules for evaluating of JetStream2, MotionMark and Speedometer browsers tests

Points	PC			Mobile			Tablet		
	JetStream2	MotionMark	Speedometer	JetStream2	MotionMark	Speedometer	JetStream2	MotionMark	Speedometer
1	79,025 - 85,781	117,83 - 146,564	67,1 - 73,88	28,0 - 32,6	112 - 128	26 - 29,2	15-18	51-52,2	15-15,8
2	85,782 - 92,537	146,565 - 175,298	73,89 - 80,66	32,7-37,2	128,1 - 144	29,3 - 32,4	18,1-21	52,3-53,4	15,9-16,6
3	92,538 - 99,293	175,299 - 204,032	80,67 - 87,44	37,3-41,8	144,1 - 160	32,5 - 35,6	21,1-24	53,5-54,6	16,7-17,4
4	99,294 - 106,049	204,033 - 232,766	87,45-94,22	41,9-46,4	160,1-176	35,7-38,8	24,1-27	54,7-55,8	17,5-18,2
5	106,050 - 112,805	232,767 - 261,5	94,23-101	46,5-51	176,1-192	38,9-42	27,1-30	55,9-57	18,3-19

Table 12 shows the evaluation rules for the JetStream2, MotionMark and Speedometer tests criterion. The rule is that the smallest value is subtracted from the largest value and the difference is divided by 5 equal steps. For example, for PC, the lowest JetStream2 reading was 79,025 and the highest was 112,805. Then the difference was divided into 5 equal steps. The same method was used in Table 13.

Table 13. Rules for evaluating browser memory usage

Points	Memory usage after 0 minutes of work			Increase in memory usage after 10 minutes of use		
	PC	Mobile	Tablet	PC	Mobile	Tablet
5	379,2 - 455,5 MB	319,8 - 376,68 MB	100 - 122,71 MB	25,40 -16,53 MB	462 - 506,39 MB	29,6 -34,91 MB
4	455,6 - 531,8 MB	376,69 - 433,56 MB	122,72 - 145,43 MB	16,54 -207,67 MB	506,4-598,79 MB	34,92-40,23 MB
3	531,9 - 508,1 MB	433,57 - 490,44 MB	145,44 - 168,15 MB	207,68 - 298,81 MB	598,8 -691,19 MB	40,24 - 45,55 MB
2	608,2 - 684,4 MB	490,45 - 547,32 MB	168,16 - 190,87 MB	298,82 - 389,95 MB	961,2 -783,59 MB	45,56 - 50,87 MB
1	684,5 - 760,7 MB	547,33 - 604,2 MB	190,88 - 213,6 MB	389,96 -481,1 MB	783,6 - 876 MB	50,88 -56,2 MB

Table 13 shows the evaluation rules for memory usage. The rule is the same that was used in Table 12. The smallest value is subtracted from the largest value and the difference is divided by 5 equal steps.

Table 14. Rules for evaluating usability, security and privacy of browsers

Points	Security and privacy			Usability		
	PC	Mobile	Tablet	PC	Mobile	Tablet
1	5	4-5	4-5	9	8	8
2	6	6	6	10	9	9
3	7	7	7	11	10	10

Table 14 shows the evaluation rules for usability, security and privacy. Evaluation rules are almost the same as for Table 12 and Table 13, but and the difference between the largest and the smallest values is divided by 3 equal steps. For example, for PC, the lowest security and privacy result was 5 and the highest was 7. Then the difference was divided into 3 equal steps.

Table 15. Browser evaluation results

	PC				Mobile				Tablet			
	Google Chrome	Mozilla Firefox	Opera	Microsoft Edge	Google Chrome	Mozilla Firefox	Opera	Microsoft Edge	Google Chrome	Mozilla Firefox	Opera	Microsoft Edge
JetStream2	5	1	5	5	5	1	5	5	5	1	5	5
MotionMark	5	1	4	5	5	1	5	2	5	1	5	1
Speedometer	5	1	2	5	5	1	5	2	1	3	5	3
Memory usage	8	2	6	9	10	2	6	3	7	2	9	9
Security and privacy	3	5	3	3	3	5	2	3	3	5	2	3
Usability	2	1	3	2	2	1	3	1	2	1	3	1
Score:	28	11	23	29	30	11	26	16	23	13	29	22

Table 15 shows the results of evaluating browsers across all platforms. Before Formula 1 is applied, the best browser for PC is Edge, for mobile – Google Chrome, for tablet – Opera.

Regular user

Table 16. Browsers evaluation results for regular users

	PC				Mobile				Tablet			
	Google Chrome	Mozilla Firefox	Opera	Microsoft Edge	Google Chrome	Mozilla Firefox	Opera	Microsoft Edge	Google Chrome	Mozilla Firefox	Opera	Microsoft Edge
JetStream2	10	2	10	10	10	2	10	10	10	2	10	10
MotionMark	10	2	8	10	10	2	10	4	10	2	10	2
Speedometer	25	5	10	25	25	5	25	10	5	15	25	15
Memory usage	8	2	6	9	10	2	6	3	7	2	9	9
Security and privacy	15	25	15	15	15	25	10	15	15	25	10	15
Usability	10	5	15	10	10	5	15	5	10	5	15	5
Score:	78	41	64	79	80	41	76	47	57	51	79	56

Table 16 shows the results of browser evaluation for a regular user using Formula 1.

According to the results, the best option for PC use for a regular user is Microsoft Edge browser. For mobile devices, the best choice is the Google Chrome browser. And for tablet the most suitable choice is Opera browser.

Student

Table 17. Browsers evaluation results for students

	PC				Mobile				Tablet			
	Google Chrome	Mozilla Firefox	Opera	Microsoft Edge	Google Chrome	Mozilla Firefox	Opera	Microsoft Edge	Google Chrome	Mozilla Firefox	Opera	Microsoft Edge
JetStream2	10	2	10	10	10	2	10	10	10	2	10	10
MotionMark	5	1	4	5	5	1	5	2	5	1	5	1
Speedometer	25	5	10	25	25	5	25	10	5	15	25	15
Memory usage	8	2	6	9	10	2	6	3	7	2	9	9
Security and privacy	15	25	15	15	15	25	10	15	15	25	10	15
Usability	10	5	15	10	10	5	15	5	10	5	15	5
Score:	73	40	60	74	75	40	71	45	52	50	74	55

Table 17 shows the results of browser evaluation for a regular user using Formula 1.

According to the results, the best option for PC use for a regular user is Microsoft Edge browser. For mobile devices, the best choice is the Google Chrome browser. And for tablet the most suitable choice is Opera browser.

Advanced user

Table 18. Browsers evaluation results for advance users

	PC				Mobile				Tablet			
	Google Chrome	Mozilla Firefox	Opera	Microsoft Edge	Google Chrome	Mozilla Firefox	Opera	Microsoft Edge	Google Chrome	Mozilla Firefox	Opera	Microsoft Edge
JetStream2	20	4	20	20	20	4	20	20	20	4	20	20
MotionMark	5	1	4	5	5	1	5	2	5	1	5	1
Speedometer	25	5	10	25	25	5	25	10	5	15	25	15
Memory usage	24	6	18	27	30	6	18	9	21	6	27	27
Security and privacy	15	25	15	15	15	25	10	15	15	25	10	15
Usability	10	5	15	10	10	5	15	5	10	5	15	5
Score:	99	46	82	102	105	46	93	61	76	56	102	83

Table 18 shows the results of browser evaluation for a regular user using Formula 1.

According to the results, the best option for PC use for a regular user is Microsoft Edge browser. For mobile devices, the best choice is the Google Chrome browser. And for tablet the most suitable choice is Opera browser.

4.3 Recommendations for choosing a browser on different platforms

Below are the results of the most suitable browsers for three groups of users based on the previous testing and evaluations.

Regular user

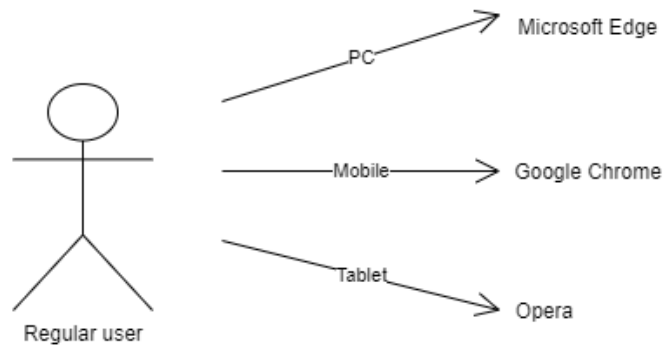


Figure 18. Browsers for regular users

For regular users, the most important criteria are browser speedometer test, usability, security and privacy.

Therefore, Google Chrome, Opera and Microsoft Edge browsers are the most suitable ones. They have many built-in features, they are fast, and they have good security and privacy.

Student

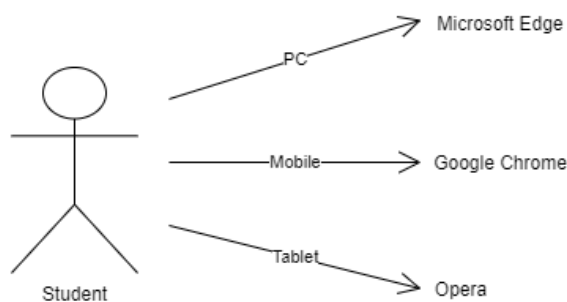


Figure 19. Browsers for students

For students, the most important criteria are browser speedometer test, usability, security and privacy.

Therefore, Google Chrome, Opera and Microsoft Edge browsers are the most suitable ones. They have many built-in features, they are fast, and they have good security and privacy.

Advanced user

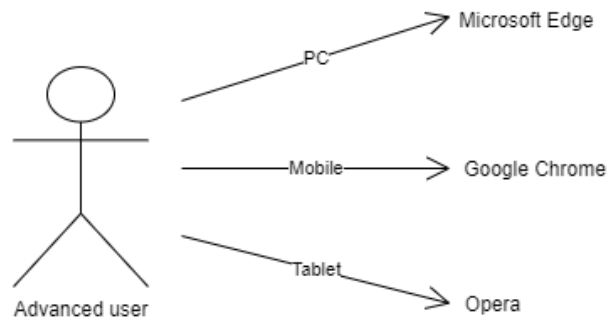


Figure 20. Browsers for advanced users

For advanced users, the most important criteria are JetStream2 test, Speedometer test, memory usage, usability, security and privacy.

Therefore, Google Chrome, Opera and Microsoft Edge browsers are the most suitable ones. They perform well in processing Internet protocols and memory usage, they also have many built-in capabilities and features, they are fast, and they have good security and privacy.

5 Summary

The aim of the work is to give recommendations on choosing a browser for different groups (regular user, student, and advanced user) on different platforms (PC, mobile and tablet).

To achieve this goal, a definition of what a web browser is has been given. Then the availability of the most used browsers on different platforms was presented. Then brief descriptions of the most used browsers were given. Then the criteria of browser evaluation were presented.

Then the test results for each criterion with an overview were presented.

Then a method for browser evaluation was provided. Then the results of a survey conducted among Internet users were analyzed and the rules for evaluating the survey were presented. Then the rules for each of the criteria of browser evaluation were presented. Then, using the method, the scores to each browser on each platform were presented.

At the end, recommendations for various user groups (regular user, student, advanced user) on choosing the most suitable browser on PC, mobile and tablet were given.

For a regular user, the best browser for PC is Microsoft Edge, the best browser for mobile is Google Chrome and the best browser for tablet is Opera.

For a student, the best browser for PC is Microsoft Edge, the best browser for mobile is Google Chrome and the best browser for tablet is Opera.

For an advanced user, the best browser for PC is Microsoft Edge, the best browser for mobile is Google Chrome and the best browser for tablet is Opera.

References

- [1] Announcing Microsoft Edge for iOS and Android, Microsoft Launcher. [WWW] <https://blogs.windows.com/windows-insider/2017/10/05/announcing-microsoft-edge-for-ios-and-android-microsoft-launcher/#Gd4AAkBxQuQfuyMf.97> (23.10.2020)
- [2] What is Microsoft Edge Legacy? [WWW] <https://support.microsoft.com/en-us/microsoft-edge/what-is-microsoft-edge-legacy-3e779e55-4c55-08e6-ecc8-2333768c0fb0> (23.10.2020)
- [3] Microsoft Edge: Making the web better through more open source collaboration. [WWW] <https://blogs.windows.com/windowsexperience/2018/12/06/microsoft-edge-making-the-web-better-through-more-open-source-collaboration/> (23.10.2020)
- [4] A fresh take on the browser. [WWW] <http://googleblog.blogspot.com/2008/09/fresh-take-onbrowser.html> (23.10.2020)
- [5] Google going its own way, forking WebKit rendering engine. [WWW] <https://arstechnica.com/information-technology/2013/04/google-going-its-own-way-forking-webkit-rendering-engine/> (23.10.2020)
- [6] Chrome for Android out of Beta! [WWW] <https://chromereleases.googleblog.com/2012/06/chrome-for-android-out-of-beta.html> (23.10.2020)
- [7] Opera is the oldest browser, and it is still surviving Jon Tetzchner, founder, Opera software. [WWW] <https://economictimes.indiatimes.com/opinion/qna/opera-is-the-oldest-browser-and-it-is-still-surviving-jon-tetzchner-founder-opera-software/articleshow/7068303.cms> (23.10.2020)
- [8] Mozilla Launches Firefox 4 for Android, Allowing Users to Take the Power and Customization of Firefox Everywhere. [WWW] <https://blog.mozilla.org/blog/2011/03/29/mozilla-launches-firefox-4-for-android->

allowing-users-to-take-the-power-and-customization-of-firefox-everywhere-2/
(23.10.2020)

[9] Firefox for iOS Now Available for Preview. [WWW]
<https://blog.mozilla.org/futurereleases/2015/09/03/firefox-for-ios-now-available-for-preview/> (23.10.2020)

[10] BROWSER. [WWW] https://prezi.com/p/11o9nszag4m_/browser/ (30.11.20)

[11] Safari 1.0 for Mac OS X: Information and download. [WWW]
<https://support.apple.com/en-euro/HT2964> (30.11.20)

[12] MOBILE SAFARI. <https://taoofmac.com/space/com/apple/iphone/safari> (30.11.20)

[13] New WebKit Features in Safari 14. [WWW] <https://webkit.org/blog/11340/new-webkit-features-in-safari-14/> (30.11.20)

[14] Samsung Internet Browser. [WWW]
<https://play.google.com/store/apps/details?id=com.sec.android.app.sbrowser&hl=ru&gl=US> (30.11.20)

[15] Desktop, Mobile & Tablet Browser Market Share Worldwide. [WWW]
<https://gs.statcounter.com/browser-market-share/desktop-mobile-tablet/worldwide/#monthly-202010-202010-bar> (30.11.20)

[16] JetStream2 In-Depth Analysis. [WWW] <https://browserbench.org/JetStream/in-depth.html> (30.11.20)

[17] Motion Mark. [WWW] <https://browserbench.org/MotionMark/> (30.11.20)

[18] Speedometer. [WWW] <https://browserbench.org/Speedometer/> (30.11.20)

[19] The Best Browsers, Compared with Data: Chrome, Firefox, Edge, Opera, Safari, and Vivaldi. [WWW] <https://www.process.st/best-browser/#data> (30.11.20)

[20] Какой браузер самый быстрый в 2020 году. [WWW]
<https://remontcompa.ru/internet/2012-kakoj-brauzer-samyj-bystryj-v-2020-godu.html>
(30.11.20)

Appendix 1 – Non-exclusive licence for reproduction and publication of a graduation thesis¹

I Alina Kogai

1. Grant Tallinn University of Technology free licence (non-exclusive licence) for my thesis Browsers and their use in smart devices, supervised by Vladimir Viies
 - 1.1. to be reproduced for the purposes of preservation and electronic publication of the graduation thesis, incl. to be entered in the digital collection of the library of Tallinn University of Technology until expiry of the term of copyright;
 - 1.2. to be published via the web of Tallinn University of Technology, incl. to be entered in the digital collection of the library of Tallinn University of Technology until expiry of the term of copyright.
2. I am aware that the author also retains the rights specified in clause 1 of the non-exclusive licence.
3. I confirm that granting the non-exclusive licence does not infringe other persons' intellectual property rights, the rights arising from the Personal Data Protection Act or rights arising from other legislation.

01.12.2020

¹ The non-exclusive licence is not valid during the validity of access restriction indicated in the student's application for restriction on access to the graduation thesis that has been signed by the school's dean, except in case of the university's right to reproduce the thesis for preservation purposes only. If a graduation thesis is based on the joint creative activity of two or more persons and the co-author(s) has/have not granted, by the set deadline, the student defending his/her graduation thesis consent to reproduce and publish the graduation thesis in compliance with clauses 1.1 and 1.2 of the non-exclusive licence, the non-exclusive license shall not be valid for the period.

Appendix 2 – Survey

Internet survey done by using Google Forms

Survey of Internet users

*Required

What category of Internet users do you consider yourself to? *

Regular user

Student

Advanced user

Which of the following are the most important criteria for you when using a web browser? (up to three answers) *

Browser performance

Processing quality of graphic elements

Browser speed

Device memory usage

Security and privacy

Usability