Higher Education Diploma in Software Engineering with emphasis
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Responsive Web Design for Modern Devices

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Abstract

A new device gets released almost bi-weekly, some offering a unique take on resolution or aspect ratio. For a web developer, this means that they have to constantly adapt and respond to how modern devices interact with the web, and create solutions that work for the visitors. This puts a lot of pressure on the developer to create a good, responsive webpage that is not expecting a certain device, but rather works fluently no matter the exact size of device.

In this study this development is researched and discussed, from the viewpoint of what the differences are between established and future devices, what developments that might arise tomorrow and how to react to these as a developer. The goal is also to research what methods of responsive web development works best with these devices, and what might become an issue when newer devices are released and becoming widely used.

The research is split up into two parts, one part comparing three popular frameworks and their responsiveness-related functions and the second part reviewing earlier work regarding responsiveness for modern devices.

Modern, well developed frameworks offer a lineup of functions for responsive web development, most which integrate well when met with non-standard resolutions or devices with the tradeoff of being more heavyweight and less customizable. Research concluded that modern frameworks are covering most aspects of responsive web development, and offers a good base to implement responsive web development for future devices.

Developing from having two different webpages, one mobile and one for a home PC, now almost every large webpage implements a responsive and adaptable interface which fits many more devices without slotting them into a specific niche. After this became standard, more and more unique devices could reliably browse the web. What is left is a discussion regarding what the future might hold in the case of other input devices such as voice input, small displays such as smart watch displays, and how this technique can be adapted to handle these devices as well.

Keywords: Responsive Web Design, Modern Device Development, Mobile Applications

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Chapter 1 Introduction

1.1 Background

The Internet is based on that the person in front of the web application is using a monitor in front of them, together with a mouse and a keyboard. When the mobile phones and other portable devices later took place as the leading web browsing device, the development had to adjust accordingly.

Devices used for web browsing today are many. Other than the most popular devices such as mobile phones, there are devices such as foldable phones and car infotainment systems which helps us to navigate the world wide web. Today, only about 42 percent of web visitors use a computer [39], pointing towards the decline of computer-related web browsing together with the increase of other means of browsing. This leads to web developers needing further adjustments to fit the ever-changing array of devices.

This report is meant to reflect and research how the web application of the future might need to be shaped in order to fit the demands, as well as what already existing methods solves these issues.

A web application with good responsiveness adapts well towards different device screen sizes and aspect ratios, displays the content well without removing or hiding important information. Text should fit as much of the screen as possible while not being too large to read, images should be easy to see and menus, lists or tables should be easy to navigate.

This means that the developer needs to implement methods to change the layout of the information displayed at certain moments, and in some cases even remove information from the web application. As P. LePage [33] displays in his article *Responsive web design basics*, this puts a lot of work in the hands of the web developer in order to reach a good level of responsiveness in your applications.

1.2 Scope of Research

To aid and direct the purpose of this research paper, a scope is introduced.

This research paper is meant to add on to the continuously ongoing discussion regarding web responsiveness. It is meant to compare what methods are best fitted for development, and how to think when developing a webpage for multiple devices.

The research is aimed towards prospective or new web developers, and to give an insight to how web responsiveness has evolved and how to adjust towards today's devices. Not all web responsiveness methods will be mentioned, nor will all frameworks or techniques. The frameworks and methods will be discussed from a most-popular viewpoint, and will not cover all edge cases.

1.2.1 End goal

By performing and accomplishing this research, the idea is to reach a cross-section between methods that are already existing, and the devices that these methods are well-fitted towards. Further, also to contribute towards the discussion on what new methods and ideas need to be implemented or explored further, to better fit a growing market of devices.

Chapter 2

Related Work

2.1 Earlier works and discussions

This subject has long been in discussion, more or less since web browsing was normalized on phones. This results in there being quite a few discussions, studies and papers released referencing the subject responsiveness. Below I have summarized a few works I deem relevant to this research paper. As mentioned the below sources are summaries, which will be further discussed and compared in a later part of the report.

- Voutilainen, Salonen, Mikkonen is in their research paper [45] published 2015 discussing a case study regarding the evolution of responsive web technologies within different frameworks. They also cover what methods might work more or less efficiently than others in the event of a new or differing device resolution. This article is written from the viewpoint of how a web developer can configure their web development projects to better fit different devices on the market today.

  Voutilainen, Salonen, Mikkonen also chose to cover a bit of the history regarding phone and device browsing, and how it has affected how a web developer is developing today. This research paper discusses the web responsiveness implementations in detail. We will be comparing a handful of CSS frameworks later on in this video discussing their possibilities, while Voutilainen, Salonen and Mikkonen's research paper more closely displays how to implement them effectively.

- In 2011, the author and developer Stephen Hay tweeted "There is no Mobile Web. There is only The Web, which we view in different ways. There is also no Desktop Web. Or Tablet Web. Thank you." [40] Hay shared the point of view that a webpage should not be seen as different depending on the device it is aimed at, but rather just a restructure of the same page. His viewpoint is of a developer, constantly changing to be able to accommodate upcoming devices.

  Hay continues to press that a webpage should not be seen as "mobile website" only when the layout is changed, but rather just a "webpage". This is an interesting approach, but ties well into the web responsiveness discussion considering a method might be to simply develop a webpage that dynamically changes, and therefore should fit most if not all modern devices.

- In 2014, Mikkonen (as mentioned earlier) together with Taivalsaari and Systä wrote an essay regarding the device development over the years. [42] This research paper is aiming more towards the development of multiple-device ownership, and what will happen with programs that are meant to seamlessly work on multiple devices. It is not necessarily aimed towards web development, but rather application development as a whole.

  This could be put in relation to the development of web applications, since there are a lot of similarities. This research paper also analyzes how many devices an average person has, and how these interact with eachother.

These articles and research papers closely discusses this topic, and is relevant in a few ways that will be more intricately discussed later on in this report. They are all discussing the topic web responsiveness, but from different viewpoints. One article is considering how many different devices a single person might have, while another article discusses the viewpoint from the developer and how to tackle the multiple-device development issues that might occur.

Chapter 3

Method

3.1 The Approach

The area that this research project is aiming to explore is how changes in web application responsiveness has evolved over time. Furthermore, to explore how you as a developer can prepare and work against the upcoming challenges that emerge from the development of web-accessing devices.

This analysis is meant to research the continuous web responsiveness development that has proceeded since different types of devices has started to spread. Terms will be used such as “established“ devices, which are referencing devices widespread and used today, with a common resolution such as 1920x1080, or a device with the aspect ratio around 16 by 9.

The term “newer“, “modern“ or “alternative“ devices will also be used, referencing devices that break the traditional size, format or this traditional aspect ratio. Examples include the Galaxy Z Fold 3 that has an aspect ratio of 22.5:18 [35], or the Huawei Mate Xs that has an aspect ratio of close to 1:1 when folded out fully. [24]

To tackle the comparison and research regarding the development of this fundamental pillar of web development, four research questions were established to easier frame the results.

3.1.1 Q1: What are the noticeable differences regarding web responsiveness between established devices and newer devices?

The answer to this question is meant to frame what important differences there are between different devices, and the challenges that differing or modern devices might introduce.

To achieve an answer to this question,

3.1.2 Q2: How do already established frameworks for responsiveness applications interact with unique or differing devices?

When further researching the methods that are currently used across the internet, what responsiveness applications are best applied when introducing a non-standard aspect ratio or screen size such as a foldable phone?

To give an answer to this question, three modern frameworks will be researched and compared. The framework functions and support will then be compared with factors that unique or differing devices might change, to achieve an insight to how these frameworks might work together with a unique device.

3.1.3 Q3: What or which responsiveness techniques are well suited for modern devices?

Since modern frameworks implement several features and approach angels, this question is meant to frame what methods are better suited and what methods should be left aside.

Using the result and discussion of the study from Q1 and Q2, a conclusion is drawn to answer the question of whether there are any responsiveness techniques that are going to reliably handle the upcoming challenges of future devices.

3.1.4 Q4: What advantages and disadvantages are there with modern devices, from the viewpoint of a web developer?

This research question aims to loop the study back towards a future-proofing viewpoint, and to add further to the conversation of how a web developer could prepare best for the ever-growing collection of devices. What is the best approach, and what has worked in the past?

To give a covering answer to this question, attained knowledge from the earlier thesis results and discussions are used to list advantages and disadvantages from the web developers viewpoint.

3.2 The Outline

During this research paper an approach has been taken to try to widen the view of how web responsiveness works today, how it has been developing overtime and how today's and speculatively tomorrow's devices perform with the already existing techniques.

Aiming at covering these concepts as good as possible, the research was split up into two parts which will be further explained below.

Part One - Framework comparisons

This part is comprised of three popular HTML frameworks, and a simple web page implemented in each one. These frameworks have different viewpoints on web responsiveness, and the aim is to discuss and compare the results that are achieved together with the approach each framework has towards device responsiveness.

The three frameworks used are Foundation[21], Skeleton[11] and Twitter's own Bootstrap[44]. All three frameworks claims to be intended for easy web development while maintaining a simple approach towards device responsiveness.

These frameworks have been chosen because of their widespread popularity, topping lists as the easiest and most used frameworks within HTML/CSS development. [1, 36, 43] I also deemed the frameworks different in the case of sizes where Skeleton is a bare-bones framework aiming towards complete control over the framework parameters, while a framework such as Bootstrap is a lot more covering and Foundation covering most functions of the three. These web pages are compared from a critical standpoint, and is put in relation to the historical development of web technologies.

Three separate webpages were constructed from the three frameworks, using documentation and in some cases other guides for ease of implementation. The aim was to partly create three similar webpages supporting the same information, but also to test the different features the frameworks offer to create a more responsive webpage.

The frameworks offer different responsiveness integrations, which were compared and investigated.

These factors were then split up into different categories, upon which the frameworks were compared. These chapters were:

- Introduction, information regarding the framework itself
- Webpage Information, information about the implemented webpage
- Grid System, if the framework offered one and what it supported
- Styling and Normalization, to unify different devices styles before applying the developers own formatting
- Responsive Functions that the framework offers
- Other Functions that might be deemed relevant

The most important category, Responsive Functions, contains aspects that were researched. These were

- Table formatting, legibility and responsiveness
- Responsive navigation, or menu solutions
- Image responsiveness techniques
- Recommended approach towards web responsiveness
- Separate functions aimed specifically to improve responsiveness

The reason these were the chosen parameters was because of their importance in a responsive web application. Some areas are also very wide, resulting in different solutions to issues depending on the framework.

These factors are used when deciding what is beneficial for a framework in this comparison, and what might be detrimental in the aspect of responsive web development.

Part Two - The literature study

The literal study aims at discussing earlier research in similar topics, and achieving a basic timeline of how this discussion has developed over the years. It also serves a purpose of giving a broader view of web responsiveness, and whether or not this discussion can be further developed or if it is already matured.

The literal study is meant to bring more substance to this research paper, comparing this widely discussed topic to a timeline and discusses what has changed over time, and how this discussion has developed when the web browsing experience has gone through changes as a whole.

Chapter 4

Results and Analysis

4.1 Part One: The Framework Comparison

4.1.1 Preface

The three frameworks that are used, as mentioned before, are Foundation, Skeleton and Bootstrap. [11, 21, 44]

Skeleton is representing itself as the most lightweight framework of the bunch, with only around 400 lines of code in total. [21] The reason for this is because Skeleton aims more towards simplifying and making itself a "starting point", instead of being a framework. Skeleton is, for example, not using any JavaScript to implement their functions or features. Skeleton is purely implemented using a CSS file, making implementation uncomplicated and quick. Thus, Skeleton is a lot more simpler than both Bootstrap and Foundation.

All three frameworks aims at a "mobile-first" developing style, meaning that smaller screens are prioritized. Bigger screens will then inherit this style, and changed until it fits the bigger screens aswell. Another reason for this approach is for smaller devices (such as phones) to not have to parse big CSS-files irrelevant to the device, and instead when a viewport is bigger than a set threshold the device will parse further CSS code implementing changes to the original, "small" style. [see 11, Media queries]

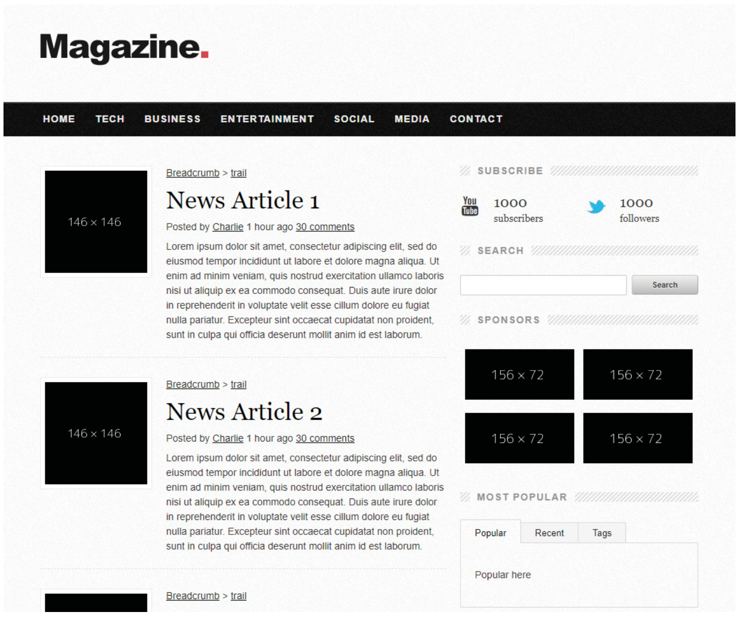
All three frameworks are offering a 12-slot grid development-style, meaning the webpage is split up into twelve parts. Information and objects can then be adapted and set into this 12-slot grid and adjusted dynamically. This is opt-in for Bootstrap and early in development, but the other two frameworks are nudging the developer to use this style of responsive design.

4.1.2 Framework One: Skeleton

Intro

The first implementation is Skeleto. Figure 4.1 contains a screenshot of the implemented webpage and its design.

Skeleton is the most lightweight framework of the three, with around 400 lines of code in total or about 12 kilobytes. It is meant as a starting pillar for CSS implementations, and is based on a 12-slot grid system. The grid system is the centerpiece of Skeleton, since it is a very slim framework with fewer extra features or functions.



Breadcrumb > trail

News Article 1

Posted by Charlie 1 hour ago 30 comments

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News Article 2

Posted by Charlie 1 hour ago 30 comments

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Breadcrumb > trail

Figure 4.1: Skeleton, Arrival view

The Website

The webpage that was implemented using Skeleton is a blog-style webpage containing mainly news articles. The implementation also contains a header menu with links, and a sidebar with ad-space and social media links.

Grid System

There are preset breakpoints in Skeleton that the developer can use to create a responsive layout to their web page. This is all accomplished thanks to Skeletons grid system. The grid system acts as columns where the developer easier can control the layout, and shift the layout quickly when a specific viewport width is used.

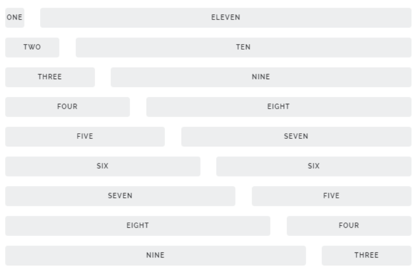


Figure 4.2: Skeleton, Grid on larger viewport

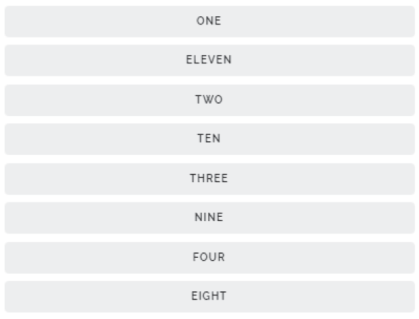


Figure 4.3: Skeleton, Grid on smaller viewport

The grid can, for example, structure the blocks in a side by side manner when a viewport is wide enough to accommodate content columns, but take up the entire width of the viewport when viewed on a smaller device. This is shown in figure 4.2 and 4.3, where a comparison is shown between a large viewport and a small viewport.

The skeleton grid system has several breakpoints, although for simplicity in this implementation three breakpoints are used. When passing the first breakpoint at 960 pixels, the margins are adjusted so the information is centered. A more critical breakpoint is where a phone user might pass is when the viewport is under 768 pixels in width. At this breakpoint the images for the articles are hidden, making place for the article headers and article text for smaller devices. Furthermore the sidebar with social links and sponsors is moved to the bottom of the page, and the footer is stretched over the entirety of the viewport.

The grid resizes itself up to 960 pixels in width, where it will stop becoming wider. This can be modified if the webpage is meant for larger displays, or for a taste preference.

Styling and Normalization

Skeleton offers preset styling for buttons, forms, tables and lists meant to normalize the styles across different devices, since some device browser implementations might style certain elements differently.

Responsive Functions

Skeleton as a framework does not support many more functions, as it is meant as a very lightweight styling framework helping with responsiveness on a basic level. Therefore this framework does not contain any responsive functions other than a few helper classes to aid in

- Image resizing following parent containers
- Making elements take up the entirety of the page
- Making elements float left or right

Other Functions or Features

Returning to the implemented web page, one final point to mention is the break point for the menu. Currently a break point is set for 768 pixels where the menu bar simply disappears. This is meant to be replaced by for example a click-down menu with a hamburger icon (for smaller screens, such as a mobile phone) although the framework does not support any dynamic menu creations.If this were to be implemented, a custom solution has to be created (or an implementation of a dynamic menu solution from another framework has to be used).

4.1.3 Framework Two: Foundation

Intro

Foundation offers a much more covering framework with several advanced features such as webpage and email formatting, responsive menu creations and automatic image resizing or replacement. It is a much more covering framework, with the downside of course that it is being a lot larger and more time-consuming to implement.

The Website

The webpage that was implemented using foundation is another magazine-style website containing articles, social media links and a header with a menu. See figures 4.4 and 4.5 for screenshots of the page.

At the top of the webpage there is what Foundation calls the "Title bar", which can be used for implementing a menu on mobile devices. It contains a search bar, and simple responsive implementations in the form of resizing depending on the viewport size. It also contains a handful of links.

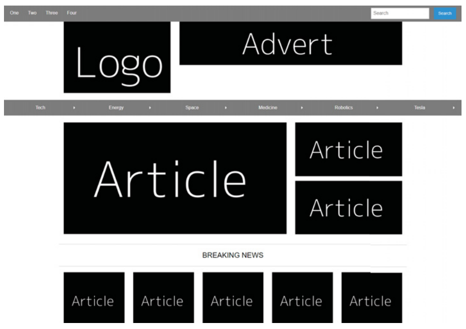


Figure 4.4: Foundation, Arrival view

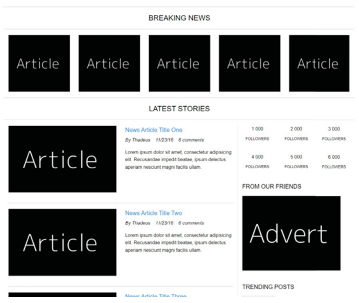


Figure 4.5: Foundation, Article view

Grid System

Like Skeleton, Foundation also implements a grid system. This is a twelve-column layout supporting a customizable sizing. Other features exists to further create a responsive grid layout, including but not limited to customizable gutters (space between grid columns), offsets to move grid blocks left or right, and the grid being fully nest-able to create special layouts.

Foundation also supports several different grid types, one of them being the "XY Grid" [20], which is a more advanced grid system supporting placing columns beside each other, filling up available viewport space and their relation between such as the above or below each other.

This grid also supports more advanced functions such as automatic responsive resizing of grid elements or columns, horizontal and vertical alignment and vertical orientation of the grid.

Styling and Normalization

Foundation has a lot of styling attributes where the developer can use pre-configured packages to apply to their elements. This is prefaced by a style normalization, which normalizes the style across different browsers. As mentioned earlier, this is used for a consistent and reliable styling of web pages on different devices and browsers. [14]

Responsive Functions

The Foundation framework has wide and well-covering support of responsive implementations, having CSS classes that help when implementing items like embed videos, images, navigation-menus and table formatting.[17, 18]

Foundation also supports classes you can apply to elements which hides or displays the elements depending on the screen size and other factors. [19] Screen sizes are not the only option to handle whether to show or hide an element using Foundation; You can also use factors such as the orientation of the viewport (landscape or horizontal), if the device has dark-mode enabled. Even technologies such as showing or hiding specific elements to screen readers can be implemented using these classes.

The Menu System

Foundation supports a powerful responsive navigation system which makes it easy for developers to implement responsive menus. The menus resize automatically depending on viewport or device size, and supports changing functionality depending on these factors. [18]

The implemented website takes advantage of this, and is currently supporting two different menus depending on the viewport size. (See figure 4.6 and 4.7) The larger menu is a simple drop-down menu which is displayed on viewports that are larger than a specific viewport size. When the viewport is smaller (and the website is assumed to be displayed on a mobile device), the drop-down menu is hidden. The drop-down menu is then replaced by a hamburger-style menu button which displays a drilldown-style menu [15] The drill-down menu takes better advantage of the small screen size, while still displaying all menu options efficiently and comprehensible.

When this menu is replaced with a drill-down menu, the same breakpoint is used for a few other factors aswell. The webpage logo is stretched across the entire viewport, aswell as the articles together with their text. The titles and their descriptions are resized thanks to Foundations breakpoint classes, and take up almost the entire viewport to be able to be viewed on smaller devices.

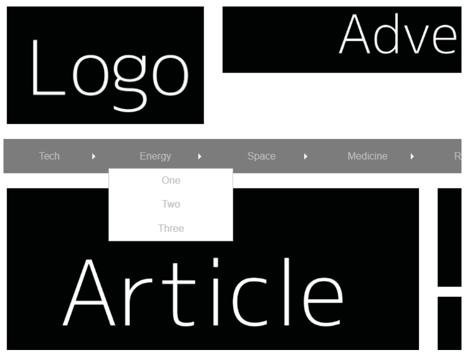


Figure 4.6: Foundation, Larger viewport menu

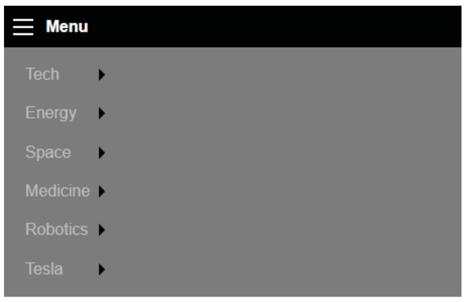
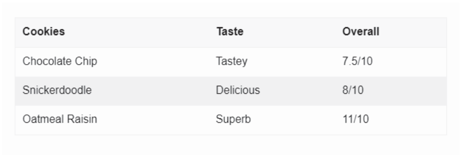


Figure 4.7: Foundation, Smaller viewport menu

Other Functions or Features

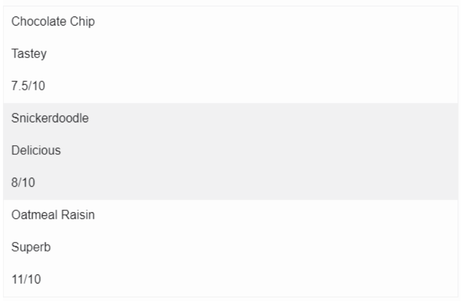
Some other noteworthy functions that Foundation offers (from the responsiveness viewpoint) are:

- Table formatting. Foundation offers "stacking" tables on smaller screens, making the table data more legible in a scrolling environment. See figure 4.9 and 4.8.
- Foundation "Interchange", which is a plugin that helps a developer change an image with a smaller sized one. This is meant to cut down on bandwidth for smaller devices, not needing to load larger images than their device can display anyways. [16]
- A "Responsive Embed" helper class, helping to make sure that information wrapped in this class is maintaining its aspect ratio. An example would be to make a video maintain an aspect ratio of 16 x 9 unrelated to viewport width or size.



Cookies	Taste	Overall
Chocolate Chip	Tastey	7.5/10
Snickerdoodle	Delicious	8/10
Oatmeal Raisin	Superb	11/10

Figure 4.8: Foundation, Normal table



Chocolate Chip
Tastey
7.5/10
Snickerdoodle
Delicious
8/10
Oatmeal Raisin
Superb
11/10

Figure 4.9: Foundation, Stacked table

4.1.4 Framework Three: Bootstrap

Intro

The Bootstrap framework is created by developers working under the umbrella of the Twitter team, and is of a similar size to Foundation. It is a more advanced framework, offering several smart functions and possibilities to create a responsive and efficient web page.

The Website

The web page implemented using Bootstrap is a blog-style or news-magazine-style web page, similar to the Skeleton and Foundation implementations. See figure 4.10.

The implementation contains a header with a title, some links to different subjects, a search bar and sign up/subscribe buttons. There are postcard-style entries where different articles together with images are shown, and some enhanced articles that take up a larger portion of the viewport. Furthermore comes a list of posts, together with a smaller sidebar containing links to archived posts and some text blocks.

Grid System

In addition to the previously mentioned responsive functions, Bootstrap offers a grid for easy implementation of responsive pages. The grid consists of twelve columns, where the developer has full control over how elements take up space and interact with each other.

To help, there are six different viewport sizes ranging from sm (small) to xxl. These are used as preset breakpoints where the developer then can decide how the content should act when displayed on a specific sized display.

By default the grid is meant to help the developer size elements (or entire columns) in relation to each other, but other responsive functions are also helping to maintain an intended layout of the content. The developer can make a certain group of grid elements stack when at a specific break point, but let other content in the same grid remain side-by-side at all viewport sizes. The developer can also play around with the amount of space each grid element take up, and dynamically change a grid element depending on the viewport size.

Styling and Normalization

Bootstrap builds upon a style normalization, or as they like to call it a "Reboot." [7]

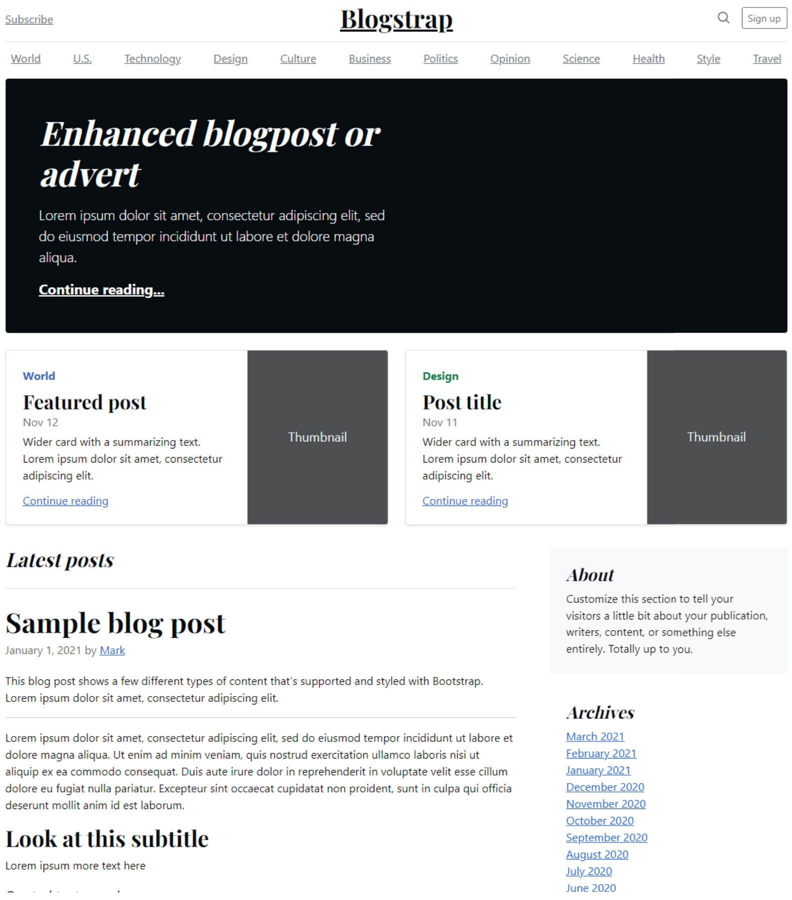
As mentioned with the other frameworks, this style normalization helps the developer maintain an easy to work with, consistent styling throughout the web page. This function results in the content being legible, consistent and well marginalized for layout purposes. It also serves purpose as a kind of safety measure, preventing some elements that might normally be resizable to instead be only a specific size to prevent that element to break an intended layout.

There are also some improvements over default CSS rules other than some added margins. One example is that important functions like elements that have the *hidden*-property is made *!important*, preventing some cases where the hidden property is de-prioritized.

Responsive Functions

The Bootstrap framework contains plenty different functions that help the developer to create a responsive web page. For images, there are helper classes such as *img-fluid* which makes the image respond according to its parent size, making the image play well with resizing *div*s. There are also a few helper classes for aligning images both vertically and horizontally. [6] Tables are also not left out, supporting helper classes that makes any table that is larger than the viewport width to become scroll-able sideways.

When adding other types of embed content to your web page such as an *iframe*, there is a helper class meant to support the content maintaining a certain aspect ratio and instead resize accordingly. For example, one could make sure that an embed video maintains an aspect ratio of 16x9 when resizing the viewport.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Sample blog post
January 1, 2021 by Mark

This blog post shows a few different types of content that's supported and styled with Bootstrap. Lorem ipsum dolor sit amet, consectetur adipiscing elit.

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Lorem ipsum more text here

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February 2021
January 2021
December 2020
November 2020
October 2020
September 2020
August 2020
July 2020
June 2020

Figure 4.10: Bootstrap, Arrival view

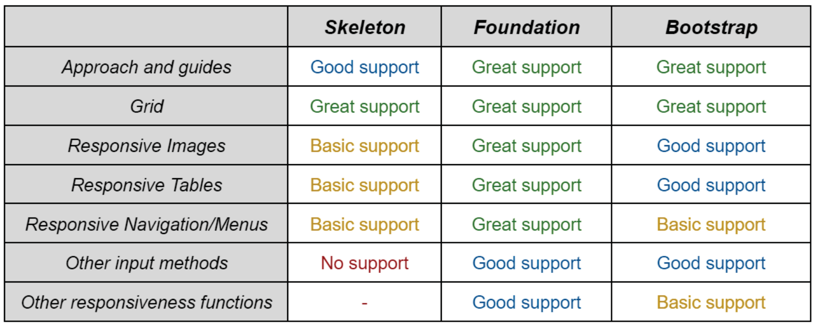
Other Functions or Features

4.1.5 Similarities and Differences

As can be seen in the figure 4.11, there are a few differences between the studied frameworks. Worth noting is that, as mentioned earlier, the Skeleton framework is a light framework not offering as many functions. It's grid is not as developed as the other two frameworks, although still recieves a "Great support" since it is completely written in CSS as opposed to Foundation and Bootstrap which acts more as complete replacements of existing style.

Sizes

The strength and selling-point in the Skeleton framework is clearly its minimal size and smooth approach to framework development. In comparison to Foundation and Bootstrap, Skeleton is barely even a framework and more a basis for the developer to, in a very light manner, get a solid foundation for their project. This can prove to be more efficient and easier to work with, with the obvious drawback of missing some very good features such as specific functions or preset breakpoints for easy responsiveness management.



	Skeleton	Foundation	Bootstrap
Approach and guides	Good support	Great support	Great support
Grid	Great support	Great support	Great support
Responsive Images	Basic support	Great support	Good support
Responsive Tables	Basic support	Great support	Good support
Responsive Navigation/Menus	Basic support	Great support	Basic support
Other input methods	No support	Good support	Good support
Other responsiveness functions	-	Good support	Basic support

Figure 4.11: Comparison between framework functions

Responsive functions

More specifically, when implementing a web page intended to be easily usable on unique or special devices, there are a few functions that help the developer achieve this goal.

- A good developing practice comes first, preferably a mobile-first approach. This is supported and even encouraged by all three frameworks, and provides a fast and responsive web page that is easy to implement and fits well with most device aspect ratios or sizes.

- A good way to implement figures and images. Foundation offers an efficient plugin for swapping images out when reaching a certain threshold, saving data for smaller devices and speeding up load times. Skeleton and Bootstrap does not implement these functions, although the same result can be achieved with an arguably better result using *srcset*, a built-in function of html. [10]

- Having a responsive information layout. No important information should be lost when using a uniquely sized viewport and should instead be repurposed, resized or repositioned to better fit the device. The grid implementation found in all three frameworks helps achieve this, and to decide how much space certain aspects of the page should take up depending on the device size.

Grid differences

When comparing grid implementations Skeleton comes in at a very light pace, while Bootstrap and Foundation offers more functions. Bootstrap offers functions like stacking a certain grid element at a certain display size (and making some other elements only stack at a different display size), horizontal or vertical grid element alignment, reordering grid elements depending on display size and fully customizable grid layout and gutter (margin) size.

The Foundation grid by comparison also includes stacking at specific display sizes, although only by row and not down to each grid element as Bootstrap. Foundation also incorporates other functions such as offsets for customizing element placements, removing the grid gutter at specific viewports aswell as inverting the stacking behaviour, stacking the elements by default then unstacking at a specific, larger viewport.

Navigation

One large point differing these three frameworks is how they handle menu responsiveness. Skeleton for example does not offer any help when creating a responsive header menu for a webpage, meaning that displaying different menus depending on the size of the viewport and breakpoints has to be fully implemented manually. In comparison, both the Foundation and Bootstrap frameworks already support fully implementable solutions to this in the form of menus with specific CSS classes added onto them, which then later can dynamically be called depending on the size of the viewport. [5, 18]

Other points

When determining the size of the device used, the width of the viewport is measured. The horizontal size is not measured nor used in any of the three frameworks when estimating the device size. This also means the aspect ratio is not used when determining what methods to apply to display the application and its content.

4.2 Part Two: The Earlier Discussions

4.2.1 Historically

Responsiveness has always been an important subject for web developers. In 2013, Forbes discussed in an article how the future of the web is going to pan out. The article details an interview with *Jody Resnick*, then CEO of digital marketing agency Trighton Interactive, who explained that *“Responsive websites provide continuity between different viewing contexts, remaining completely agnostic to the type of device used and the size of the screen it has. What this means is that the same website will present an optimized layout regardless of which device it finds itself being loaded in.“* [22] Resnick then continued to predict that webpages not implementing a more fluid or adapting responsiveness technology will lose visitors, and also saves the company lots of costs down the line when only having to maintain a single responsive solution as opposed to an implementation for every device.

This is further reinforced by Stephen Hay 2020, stating that "“There is no Mobile Web. There is only The Web, which we view in different ways. There is also no Desktop Web. Or Tablet Web.“ referencing the fact that a developer should not create different pages for specific devices, but instead implement a dynamic solution. [40].

4.2.2 Early implementations

An article from 2010 written by Ethan Marcotte displays the view on the topic of responsiveness during that era of web development. Different device sizes were not covered, but rather if a device had a landscape mode or portrait mode. The focus on this article aimed more on the (back then) newly introduced media-tags, and how they can be implemented. (Media tags were worked on as early as 2001 [46], although it did not become a W3C standard until after browsers started supporting it around

2012. [13]) During the article, Marcotte further discussed media-tag use-cases such as changing a menu layout on a smaller device, or moving logos and images to fit a smaller screen better. These are both ideas later implemented for easier use by the example frameworks mentioned earlier in this report.

In 2014, during the User *Interface Software and Technology* conference, Gilbert Louis Bernstein and Scott Klemmer proposed a solution to the responsiveness discussion. Their idea was a system that is interpreting current website content, and tries to rearrange the content in a way to fit the device. It was intended to work similarly to the grid systems found in earlier mentioned frameworks. A working prototype was also developed for proof of concept using a small sample size of webpages, but the project was never actualized more than so. [28]. The programming practices back in 2014 were noticably different regarding responsive web design as opposed to today, which might be the result of webpages being visited more often on phones now than ever before, up from 30 percent in 2015 to 55 percent at the end of 2021. [8] According to StatCounter, this number is even up to 58 percent today while the market share back in 2014 was only 32 percent mobile devices. Back in 2012, when browsers started supporting responsive implementations, the mobile web visitors were measured to only 12 percent. [39]

4.2.3 Further research

As mentioned in the introduction of the report, Mikkonen together with Taivalsaari and Systä wrote an essay regarding the device development over the years and how this entails a software development which seamlessly integrates between all these devices. [42]

Their viewpoint on modern development is not specifically tied to the difference between two devices, but rather how these devices integrate seamlessly. As written by themselves, "We argue that the transition to multiple device ownership will eventually lead us to liquid software – an approach that will allow data and applications to seamlessly move between multiple devices and screens.“. Their vision of the future is the ecosystem in which people can seamlessly switch between all their different devices during the day, and the software supporting this in an expected manner.

Chapter 5

Discussion

5.1 Prefacing words - Discussion

There are a lot of different opinions and articles regarding web responsiveness. Some argue it is always going to change and impossible to predict, while others maintain a view where if you develop a good responsive website, modern and different devices will follow.

The approach of this study is meant to investigate what the differences between established and modern devices are, regarding their interaction with a webpage. Furthermore an investigation of how the already applied methods now apply to the new devices, and which are best-fitted for this scenario. Framing this result in one single report will be difficult, since there are a lot of different devices paired with a lot of different techniques.

5.2 The Framework Comparison

Starting with the framework comparison, there are a few interesting points worth mentioning.

5.2.1 Navigation and Menus

The menu and navigation systems from the different frameworks are mostly conventional, with Foundation being in the front of all three by a mile. [18]

Skeleton has no menu implementations at all [11], leaving the work to the developer to create and maintain a responsive navigation menu. Bootstrap has a basic implementation of navigation bar responsiveness, helping the developer to hide the entire navigation bar behind a button. [5] This might prove helpful and even cover most cases for a regular responsive web page, although offers lacking customizability. On the other hand, Foundation offers a very well implemented solution to responsive navigation, with the possibility to switch seamlessly between different styles of navigation bars depending on chosen factors such as screen resolution or orientation. [18]

When trying to adapt a webpage to modern and future devices, versatility is key. To be able to change aspects of your website depending on a multitude of factors will prove very useful when and if unique or special devices will become a new norm, which is why I deem Foundation's navigation bar implementation to be the most powerful of the three. It could also be argued that Skeletons view is the greatest for adaptability, considering Skeleton is more of a blank slate than the other frameworks. This means implementations of other more specific menu or navigation systems could be implemented, resulting in already existing navigation systems to add dead weight to the web application.

5.2.2 Input and Interaction

Input devices

Modern devices offer different types of inputs. Stylus-style browsing modes were popular during early smart-phone era, but has since faded away slowly. The main input types of today is by touch and by mouse/keyboard combo, both which are accommodated well within web development. But even though touch is one of the mainly used input types, it is still difficult to detect if a device surely is a touch device as Stu Cox explains in an article discussing detection of touch-screen device.[9] Cox even ends this article by stating that *"For layouts, assume everyone has a touch-screen. Mouse users can use large UI controls much more easily than touch users can use small (UI controls)"*

One big difference between these two frequent input methods is hovering. Sometimes hovering an item or article gives more information about the link, or displays information and sometimes even used as navigation. This behaviour makes it difficult for touch devices to interact with the given element, with different actions depending solely on the implementation and browser. [30]

This is an area that is probable to evolve in the future, and has space for maturity in the relevance of more and more devices being touch-only.

Other Inputs

What input methods are used in future devices can only be speculated, and is very hard to predict. An input method not used very often is voice-input or screen readers, which is a very important aspect of web development that might be easy to pass on. Both Foundation and Bootstrap offer implementations of hiding or showing content specifically for screen-readers. This proves useful when implementing screen-reader-support, but might also prove useful later on if people browse the web solely through their voice and hearing. [4, 19]

There are a few other input methods that Stu Cox also mentions in his article[9], for example

- Wii-remote browsing
- Smart-tv gesture control
- finger-tracking technology and VR

These are all input methods that might become standardized in the future, however only speculations and in some cases preparation can be made at this time.

5.2.3 Ease of implementation

All three frameworks offer good support for starting a project, and both Foundation and Bootstrap maintains a very covering documentation. The strength in Skeleton continues to be its weakness aswell, being the lightweight nature of the framework. Skeleton barely has any documentation, but is only a simple CSS file containing styling and classes for breakpoint and grid implementations. Skeleton is easy to implement and build a base upon, but might need more work to approach a satisfying result. It's responsiveness capabilities are basic yet fulfilling, and builds a great base to customize further. To reach a standard of responsiveness featured in the other two frameworks some more work has to be poured in by the developer, although the Skeleton framework is also not an "end-all"-framework to cover all scenarios.

When comparing the two heavier frameworks, Bootstrap and Foundation, both offer a great toolbox of implementations not only related to responsiveness, but also ease of development and styling. This results in a bigger implementation, somewhat locking the developer to that respective framework. Bootstraps approach is a bit more hand-holding, while Foundation offers a more custom approach to framework implementation, allowing the developer to change aspects according to their own taste.

It could also be argued that the other frameworks, Bootstrap and Foundation, are more well-equipped to handle modern and future devices. Another point for these frameworks being a safer choice is the community that exists behind both of those frameworks offering help, discussions, special functions and implementations that stretches beyond the normal use-cases in special situations.

5.3 Earlier research

When reviewing earlier published papers and researches, there are a lot of different opinions regarding web development and more specifically responsiveness. Some research papers like Blodgets "Mobile First Is A Dumb Strategy" [23] claims that mobile-first is a shortsighted way of implementing a web page since the developer then de-prioritizes half the visitors devices. Some other research papers (together with the three frameworks investigated in this paper) claims the opposite, being that mobile-first design is the way forward and the easiest way to create a responsive webpage. [11, 21, 44]

Discussions around responsiveness implementations have been held since the beginning of mobile device browsing, and some standards can be traced back to as early as 2001[46], proving that the consideration has always been there. The discussions that were held when mobile-browsing became standard has evolved from speculations regarding how a mobile webpage should be implemented to that it should be the main focus, with larger stationary devices becoming secondary. The techniques discussed has not deviated too far from today's approach, but more-so cultivated to an easy-to-follow and clear guide towards mobile responsiveness.

Today, mobile responsiveness has matured substantially. There are no extensive developments going on, and most frameworks offer a covering and well-implemented solution to all responsiveness issues. This is a result of all the discussions that have been held over the years, together with trial-and-error that resulted in a optimized experience for most users.

5.4 The Summarization

5.4.1 Modern Devices

Having to develop a web page with a wider and wider target audience is difficult, especially when trying to adapt to thousands of different types of devices. The development of modern devices has both stagnated in some areas and accelerated in other areas, making the developers struggling to adapt their responsiveness implementations.

By studying the responsiveness techniques available today and how they handle unique devices, it is clear that they are well-fitting towards most devices. There are no obvious pitfalls to future devices when it comes to today's responsiveness techniques, and if the coming devices do not deviate too far from mobile devices as we see them today, the techniques might just work.

However, worth mentioning, there is some untapped potential when it comes to responsiveness implementations. It might be worth looking into aspect ratio-specific implementations, considering a web page on a watch display might be difficult to browse. On the same subject, it might be worth to implement some kind of more sophisticated user-agent decision algorithm, to make sure what kind of device the visitor is using. Using this data the web page can adapt to consider if the user is using a mouse and keyboard, a touch input or something else. As mentioned this is not something that would be useful today, but might be deemed useful in a later state when more modern devices are introduced.

5.4.2 Frameworks

As can be said with most popular frameworks, the three discussed frameworks in this research paper alls fills their space well, and are all good choices for different projects. What can be noticed is their limitations and strengths, resulting in better or worse implementations depending on the end result.

From the viewpoint of website responsiveness, the comparison becomes a little clearer. Skeleton is a lightweight implementation putting a lot of weight on the developer, but helps the developer with cases such as the grid system or preset breakpoints for easy device size management. It is a great starting point for developers when creating a web application with responsiveness in mind, but does not offer a lot of helpful functions more than the starting point it creates.

On the other hand since the Skeleton “framework“ is only based on a CSS file with a few variables, it also has an upside. There might be browsers in future devices that doesn't support JavaScript, for example a smart fridge or a watch. This results in the Skeleton webpages working wonderfully on these devices, while web applications taking advantage of more advanced futures from frameworks incorporating JavaScript instead cannot display as intended.

Between Foundation and Bootstrap, they both offer a multitude of more niche techniques both for visual parts of the web application and methods to achieve a good responsive result. Features such as Foundations automatically switching navigation-bar [18] and Foundation Interchange automatically changing images to more appropriate sizes [16] are very helpful, while Bootstrap offers features such as figure caption support that plays well with responsive reconstructions, a class to force an element maintain a specific aspect ratio or tables becoming responsive at specific breakpoints.

Chapter 6

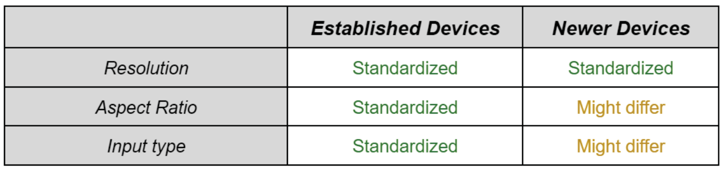
Conclusions and Future Work

6.1 Questions & Responses

6.1.1 Q1: What are the noticeable differences regarding web responsiveness between established devices and newer devices?

One always-developing section of devices over time has been screen size and resolution. According to a research paper written by three students of Simon Fraser University in Canada, the expected standard resolution of 2030 is 10k and exponentially rising further beyond. [3] This will blur the lines between what a regular monitor is and what is a portable touch device, since the resolution between the two might be more or less the same. Methods to solidify if the user is using a monitor or a portable device is unreliable [31, 41], meaning a phone in landscape mode might display the same web page layout as a desktop PC.

On the one hand this is not a crucial downside to modern devices, considering the ability to zoom and navigate a website is well developed on most modern devices. But on the other hand this might cause some web pages do make faulty assumptions regarding the visitors device, displaying navigation-menus that might be hard or even impossible to navigate using a touch screen. This phenomena can already be experienced by tablet or large-phone users [2, 37, 38], and is prone to become a staple issue when newer and even higher-resolution displays are released when paired with the unreliable user-agent detection.



	Established Devices	***Newer Devices***
Resolution	Standardized	Standardized
Aspect Ratio	Standardized	Might differ
Input type	Standardized	Might differ

Figure 6.1: Comparison between newer and older device functions

When developing a webpage with lots of information, the developer takes for granted that the user will scroll vertically. This is a point that will help future devices by a margin, since the aspect ratio of the modern device then no longer is important. If a newer device such as a fridge or a foldable smart-phone has a very long display, the display will nicely and naturally display more information on the vertical axis without any restructuring of content since the web page almost guaranteed already is prepared to be scrolled vertically. [32] The only point that might affect how these devices interact is if the web application has a footer or header, which might then be pushed further to the upper or lower sides of the device and become (marginally) harder to interact with.

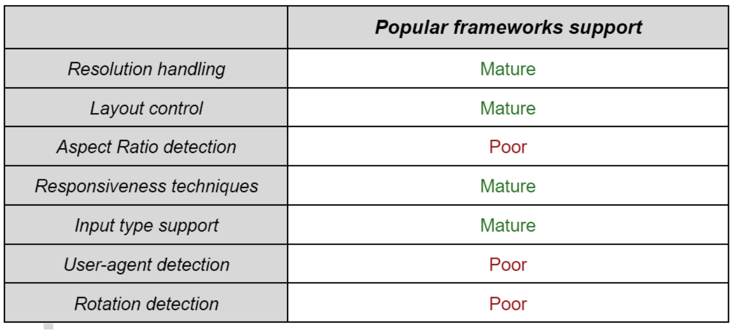
Touch devices today are almost always vertical. [26] They fit better in our hand, are easier to hold and easier to navigate menus with. In the future, more orientations might (and in some cases already have) arise. Examples of this includes circular displays for smart watches, large square displays or even large "landscape" displays in cars or other large devices like refrigerators. This offers an interesting approach for responsiveness where a display usually used together with a mouse and keyboard now instead should accomodate a touch-input for example. It could also be argued that this will not make a difference to the web responsiveness implementations currently available, although is worth mentioning as a difference nonetheless.

6.1.2 Q2: How do already established frameworks for responsiveness interact with unique or differing devices?

The resolution of a modern device varies greatly, mostly dependant on the size of the display and the use-case. Some smart watches use a resolution of 360 by 360, while some phones are up to 2700 by 1200 which makes the scaling of webpage elements very important. [25, 34] All three frameworks that were examined during this research had solutions to this, mainly being the customizable grid environment. Granted Skeleton might have issues handling images well if not manually implemented since they do not include any helper classes to this, but the other two frameworks both offered great ways to handle images responsively. This includes automatically making images take up a larger percentage of the viewport, among other points such as making a grid module take up the entire space when met with a smaller resolution.

Another great way to handle differing resolutions is Foundations implementation of tables. It is a great idea to prevent sideways scrolling data, especially on devices with smaller screens such as a smart watch. Foundation has solved this issue with a helper class that stacks tables (Previously shown in figures 4.9 and 4.8), making them easily navigated even on a small device. Bootstrap on the other hand implemented a helper class making the table scrollable sideways, which can be great to maintain a webpage structure but meanwhile is not very helpful in maintaining a legible website on a small device.

When instead using a device with a higher resolution (horizontally measured, since height is not taken into account) some frameworks are hindered by their design or responsiveness choices. Skeleton and Bootstrap both decided to set the max-width of their grid to 960 and 1160 pixels respectively on a larger display, adding whitespace to any viewport larger than that size. This can in the long term be seen as a negative measure, considering device resolution has historically always risen. A better approach might be Foundations, which is instead of setting the grid margins to a set width instead dynamically changes the width on smaller screens, always taking up a measurable width even if the display is very high resolution. [11, 21, 44]



	Popular frameworks support
Resolution handling	Mature
Layout control	Mature
Aspect Ratio detection	Poor
Responsiveness techniques	Mature
Input type support	Mature
User-agent detection	Poor
Rotation detection	Poor

Figure 6.2: Summarizing modern framework functions

On the topic of aspect ratios

Currently none of the researched frameworks take any notice of the device aspect ratio or its vertical space. The reason for this can only be speculated, but seems to be implemented for simplification purposes and because it is simply unnecessary.

The expected way for a webpage to behave is by scrolling vertically. By fetching the horizontal space and adjusting accordingly, the vertical "scrolling" space is automatically fitted depending on the device. If it is a long and thin device such as a foldable smart-phone the entire width is adjusted according to the webpages responsive implementations, and the vertical space is taken up by the information added to the webpage whether it would be articles, images or text. It should not introduce any issues since the space would already otherwise be scroll-able, and works just as well with even longer or shorter devices.

The same goes for aspect ratios closing in to 1:1, which also some foldable smartphones and smart-watches aim for. This will also not result in any major issues with responsiveness or legibility, although it might cut out some information or make some information harder to browse depending on the setup of the webpage.

In some cases, the media-query's tag *orientation* [29] can be used in addition to the frameworks. This tag reads if the aspect ratio results in a portrait-style viewport or a landscape-type viewport, and applies the given style accordingly. When implementing the Bootstrap or Foundation framework this is probably not so useful considering there already are responsiveness techniques for most aspects of the project, but when implementing the Skeleton framework this might prove useful to further style certain parts of the page such as tables or menus.

To summarize

As can be seen in the figure 6.2, the popular frameworks researched in this report handle most factors well. This translates to also being able to handle unique or differing devices, depending on what is different. When it comes to resolution, layout and content the frameworks contain lots of functions to help the developer create a responsive design. The difficulty might arise when the device has a differing input method (for example, a) or when a device screen is so large that the webpage mistakes it for a desktop, resulting in the wrong layout showing.

Also worth mentioning is that modern frameworks have no discernable ways of detecting either aspect ratio or rotation of the device. This is not an issue currently, but might become an issue if a device interacts differently depending on these factors.

6.1.3 Q3: What or which responsiveness-techniques are well suited for modern devices?

The techniques implemented in the more advanced frameworks can help create a sophisticated responsiveness layout for your project. Features like automatically replacing images with smaller sizes to save bandwidth in Foundation, or responsives table implementations in Bootstrap are very helpful when creating a web application for modern devices. Other techniques relying on older standards, such as hovering links and sections, are instead becoming more redundant.

Mobile-first

A mobile-first approach will always be a good technique to start off with when implementing a web page that should interact well with modern devices. On the one hand, mobile first implementations will lead to lighter workloads for smaller devices since they do not have to restructure the entire web page. This both saves bandwidth (which almost exclusively negatively affects mobile users), but also time for the webpage to load in. Now, when almost 50% of people browse the web on their phones [8], the time or bandwidthsaved will just become greater and greater.

Although on the other hand, some people argue that a mobile-first approach is not enough. [27] In the article *“Mobile First Is Just Not Good Enough“*, Levin & Mesibov argues that *“It is not accurate to assume that mobile is the primary experience.“* Levin & Mesibov’s point is that not every web page is assumed to be used on a phone mainly, and instead to develop specific scenarios depending on the end user to follow and to adapt each experience to those scenarios.

This can be especially noticed later on in the article, where Levin & Mesibov discusses this viewpoint and claims that *“We assume that every project needs to be mobile-friendly; so, when budgets decrease, mobile first does become mobile-only. [...] But the choice isn’t as simple as mobile or desktop. Many users switch devices mid-task, making it even more vital that we focus our content and create consistency across the experiences.“* Granted, this implementation style is both more extensive and therefore expensive, although creates a much more accustomed web application that fits more appropriately with its use-cases.

Existing techniques

Many of the earlier discussed techniques will implement very well with future devices. These are the techniques which i deem most important in the reference of differing devices.

- Responsive grid implementation (present in all three frameworks), making several break-point-specific changes to the web application easy to actualize. This will simplify the process of adapting a web page to fit any new suites of devices that might become popular.

- Image responsiveness features like Foundation's Interchange [16] simplifies adaptation of figure content to a lineup of different devices, and therefore also presumably future devices that might have different layouts or sizes.

- A good mobile-first approach will greatly increase the usability for the web page on modern devices. Adapting a large web page for smaller devices will always be more difficult than the other way around, and will simplify the process of trying to make your web application fit as many unique devices as possible. However as mentioned earlier, this method might come to change when even more devices comes to market.

- A programming practice that does not aim for a specific device or group of devices. As discussed already back in 2010 by Ethan Marcotte [12], it is important not to aim to create a specific web page for a specific device, which risks becoming a cat-and-mouse chase. Instead the developer should focus on creating a responsive web page that adapts to its device-width and input types.

6.1.4 Q4: What advantages and disadvantages are there with modern devices, from the viewpoint of a web-developer?

Modern web development techniques and standards are very mature, and contains lots of thought-out methods and implementations helping to create a responsive webpage. This also results in the developing methods fitting well with more modern and cutting-edge devices, since the techniques are developed to fit with as many devices as possible.

However, one issue that might arise is the same point made under Q1, namely the issue of high resolution portable or touch-enabled devices versus low-resolution monitors or stationary devices, blurring the lines between what webpage to display to what user. Current methods of deciding user-agent is not accustomed enough to pinpoint accurately what device the visitor is using, therefore opening risks where the visitor gets a desktop-web page on a touch-device.

The advantages of modern devices with differing layouts, input methods or sizes, are the development and maturing of already-existing techniques and implementations. Since the techniques already implemented into existing frameworks are sophisticated and covering, most of these methods will help the developer to create a web page for coming devices. As will be determined later on in this discussion, a lot of already-existing techniques fit well with modern and future devices. By implementing these methods, a large portion of speculated or differing devices are already covered and might not need any custom implementation to perform as expected for the end user.

It could also be argued that a disadvantage with newer devices is the same point made earlier, that the increase of devices to consider when creating a web page is constantly growing and therefore in constant need of attention or adaptation. This increases the responsibility for the developer to consider all possible web-devices, which is becoming an increasingly difficult task.

To summarize:

Advantages

- By not developing to a specific device, the developer has less maintaining to do during production
- Modern responsiveness techniques are adaptive to cover most outcomes, including new devices
- Mature, function-rich frameworks that covers non-standard resolutions and aspect-ratios exists

Disadvantages

- Some devices blur the lines between portable or stationary, resulting in difficulty when deciding what to display
- Non-standard input types might complicate development
- The list of different devices grows longer each day, which might result in maintenance work

6.2 Developing for modern devices

Today and future devices both play an extensive role in responsive development. We have reached a point in web development when a developer confidently can choose a solid framework and make use of the chosen frameworks responsiveness techniques, and the result is a web application which interfaces well with the larger portion of current and future devices.

In the periphery of these devices, we have the more unique devices. These include watches, fridges and fold-able phones. This challenges the developer in some cases, although in other cases the already implemented techniques and functions cooperates well with the different cases. For example, a fold-able phone when folded out is simply the same shape as a tablet, and when folded is just a regular smartphone with a slightly abnormal aspect ratio.

6.3 The Future

The future can only, as mentioned before, be speculated in. The probable advancement of web-enabled devices is leaning towards mobile devices taking over the market as per historical data, and the amount of devices that can access a web-browser is just becoming bigger and bigger. For a web-developer, to maintain a stable responsive web design can be a task at hand but will save time further down the line, especially if following the established techniques that have been discussed. When a new type of user device emerges, the developer crowd is usually quick to respond with implementations and solutions that will handle the specified problem at hand.

6.4 Future work and research

To expand on the ever-growing subject of responsive web development, a few routes have presented themselves during this analysis.

- *Image responsiveness* Text content can be wrapped and resized, Tables can be stacked or scrolled but one thing that have to remain the same size is images and figures. Confidently displaying an image on all types and sizes of devices is a challenging task requiring specific implementations, and is still not perfected. A comparison and overview of these techniques would be interesting, and maybe even new responsiveness techniques could be researched and tested.

- *Font discussions* Font is not always the most discussed subject when it comes to legibility and responsiveness, although it might play a big role if a visitor is using a physically tiny device such as a smart watch. By implementing specific font packs or text layouts such as smaller titles on specific devices, would this help responsive web development in a measurable way?

- Instead of making a web page responsive through all sizes of viewports, is it possible to specifically target a handful of breakpoints and only develop for these viewport sizes? Would this result in a better or worse web page, or is this reliant on other factors like use-case aswell?

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