What leads developers towards the choice of a JavaScript framework?

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Abstract

Context. : The increasing popularity of JavaScript has lead to a variety of frameworks that aim to help developers to address programming tasks. However, the number of JavaScript Frameworks has risen rapidly to thousands and more. It is difficult for practitioners to identify the frameworks that best fit to their needs and to develop new frameworks that fit such needs. Existing research has focused in proposing software metrics for the frameworks, which do not carry a high value to practitioners. While benchmarks, technical reports, and experts’ opinions are available, they suffer the same issue that they do not carry much value. In particular, there is a lack of knowledge regarding the processes and reasons that drive developers towards the choice.

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Objective. : This paper explores the human aspects of software development behind the decision-making process that leads to a choice of a JavaScript Framework.

Method. : We conducted a qualitative interpretive study, following the grounded theory data analysis methodology. We interviewed 18 participants who are decision makers in their companies or entrepreneurs, or are able to motivate the JavaScript Framework decision-making process.

Results. : We offer a model of factors that are desirable to be found in a JavaScript Framework and a representation of the decision makers involved in the frameworks selection. The factors are usability (attractiveness, learnability, understandability), cost, efficiency (performance, size), and functionality (automatisation, extensibility, flexibility, isolation, modularity, suitability, updated). These factors are evaluated by a combination of four possible decision makers, which are customer, developer, team, and team leader.

Conclusion. : Our model contributes to the body of knowledge related to the decision-making process when selecting a JavaScript framework. As a practical implication, we believe that our model is useful for (1) Web developers and (2) JavaScript framework developers.

Keywords:
JavaScript, JavaScript Frameworks, Human aspects of software development, human factors, decision-making
1. Introduction

JavaScript has become one of the fundamental programming languages for the Web, and it has been in the top 10 most popular programming languages since the last decade [1]. According to a survey of W3Techs, 88.2% of a billion websites analyzed rely on this technology [2]. The increasing presence and demand of Web users led to an increasing complexity of Web-based software.

Complexity in developing new applications threatens the continuous evolution of programming languages. One of the goals of software engineering is that of focusing on creating reusable code [3]. This purpose was initially accomplished by using modules, but these are limited to resolving small programming tasks. Programmers develop libraries containing pre-written JavaScript code so as to ease and shorten the development of projects. These libraries comprise functional and aesthetic aspects of Web-centric development. Libraries can be grouped according to their functionalities or they can be part of an application skeleton that is commonly referred to as a framework. JavaScript frameworks comprise a set of utilities, functions, and high-level abstractions, which have been tested in different platforms and browsers and which serve different purposes such as: visual design, charting and dashboards, animation, drag and drop, event handling, etc.

The proliferating number of implementations relying on JavaScript has resulted in increasing activity in open source communities. Several new JavaScript Frameworks are being released and others are being extended with new functionalities. The results of a query, run via Google Big Query, to identify the number of projects registered per programming language in GitHub, has shown that JavaScript is atop with more than 210000 projects.
New and experienced developers face difficulties in defining the most suitable framework to use for their projects [4, 5].

The body of knowledge in software and Web engineering research incorporates a limited number of proposals for identifying and measuring favorable and desirable characteristics of JavaScript Framework. Some proposals have focused on the quality of the software and apply ad-hoc software metrics while other researchers focus on practical aspects such as good documentation and ease of learning. A past work has identified a lack of research regarding developers’ personal experience, shared in Web communities and blogs [5].

Our paper echoes the call for research on the decision-making processes of software developers when they select technologies through the research question “What leads developers towards the choice of a JavaScript Framework?” We report a qualitative interpretative study, based on grounded theory, during which we interviewed 18 participants. The participants were decision makers in their companies or entrepreneurs, or were at least able to motivate the JavaScript Framework decision process. The results of this study offer (1) a model of features that are desirable to be found in a JavaScript Framework, and (2) a representation of the decision makers involved in the frameworks selection, which is grounded on the model. The remainder of this article is divided into five sections. Section 2 reports our literature review of the research in software and Web engineering and the practitioners’ voice. Section 3 reports how we designed the study, in terms of participants’ recruitment and interview design. The section also summarizes how the data was analyzed in terms of coding and the interpretative grounded theory ap-
proach. Section 4 provides the resulting model of eight categories and 15 sub-categories. Each item is accompanied by one or more interview snippets that brought us to elicit the particular category. In section 5 we compare our model with the existing literature, we suggest several implications, and we provide the limitations of this study. Section 6 concludes the paper.

2. Related work

The results of our literature review suggested that there has been more work conducted by practitioners—in technical blogs, reports, and dedicated websites—than what the scholarly literature have produced. Thus, in order to place our work with as much related work as possible, we considered the perhaps grayer area of practitioners’ writings, which is preceded by the academic related work.

2.1. Research

The software engineering body of knowledge has shown a limited understanding of the question we address in this paper.

Gizas et al. [6] stated that we must consider three aspects when comparing JavaScript Framework: quality, performance and validation tests on the frameworks. The authors compared the frameworks Ext.JS, Dojo, jQuery, MooTools, Prototype, and YUI. During the research they identified four different run-time versions for each language: (1) Base Version (uncompressed) which includes the minified set of core functions; (2) Compact Version, i.e. the base version with no comments and blank lines; (3) Full Compact Versions, with all the available functions in a compact format; (4) Development Kits, with all the development tools to satisfy more advanced developer
needs. They defined common functions to use for the evaluation: DOM manipulation, selectors, Ajax functionalities, basic elements of forms, functions for base event handling and functions for compatibility support and loading utilities. Gizas et al. [6] measured quality upon classic software metrics measuring size (e.g., lines of code), complexity (e.g., McCabe’s Cyclomatic Complexity), and maintainability (e.g., Maintainability). The tools used for the quality tests were: JSmeter, Cloc, and Understand. The validation tests were conducted using Yasca software utility, in combination with JavaScript Lint. Different browsers and operating systems were used for the performance tests, which were all analyzed by SlickSpeed Selectors test framework [6].

Misra and Cafer [7] introduced a complexity metric for JavaScript, called JavaScript Cognitive Complexity Measure (JCCM). The metric is intended to access the design quality of scripts. The JCCM metric formula is calculated using (1) the size in terms of lines of code containing variables and operators, (2) the number of arbitrarily named distinct variables (ANDV), (3) the number of meaningfully named variables (MNV), (4) the cognitive weights of basic control structures (BCS) such as loops, recursions, etc., and (5) the number of operators. Thirty JavaScript files from the Web were analyzed in two folds. The authors demonstrated that the metric converges to the metrics of Cyclomatic Complexity, Logical Lines of Code, and Halstead metrics. The paper does not report about any validation from the practitioners’ point of view.

Graziotin and Abrahamsson [5] introduced an exploratory model for the comparison of JavaScript Framework as a result of a qualitative research run.
with experienced Web developers. The model suggests that there are three criteria that drive practitioners towards the choice of a JavaScript Framework, namely (1) documentation, (2) community, and (3) the pragmatics of a JavaScript Framework. Additionally, the findings suggest that it is important for practitioners to have software metrics applied to a single software project implemented using different JavaScript Framework, in order to have meaningful comparisons.

2.2. Practitioners

To further investigate the overall knowledge in the field we selected some insightful developers’ personal experience and the advice they shared with others, and the most prominent technical websites specialized in our topic of interest.

According to Bennet [8], there are four parameters that a JavaScript Framework must assure in order to be considered as a great choice. The parameters are (1) a normalized event model, including attaching/removing listeners, automatic scope correction and access to the event itself, (2) a normalized wrapper around XMLHttpRequest, including the ability to specify callbacks to fire when the request finishes, (3) a set of normalized utilities for working with the DOM, especially for getting/setting styles and managing class names, and (4) facilities for creating visual animations, whether predefined or custom, which handle cross-browser timing quirks. Bennet suggested also that a JavaScript Framework should present the scripting language as it is and not make it similar to other languages, the DOM methods should be used only if wrapping is necessary for cross browser compatibility, the name of objects inside a JavaScript library should be meaningful and possi-
bly be inherent to the functionalities that the library provides, and that the
documentation is very important for easily understanding a framework and
extending its functionalities.

Reyes [9] oriented towards an analysis of the maturity of a framework by
retrieving information on how long it has been developed and how often new
updates are released. It is important to Reyes that the community behind
a benchmark consists of experienced developers. He takes into consideration
the requirements of the framework with respect to the requirements of the
Web page. Programmers should focus on the usability of the framework.
Reyes suggested checking if the framework needs continuous updates and if
the programmers are required to know the libraries very well. The analysis
focused also on the documentation, which is crucial for finding things while
on a rush.

Walsh [10] advised to analyze the velocity of the JavaScript Framework
by using MooTools Slickspeed test page. The tool runs checks on speed and
validity selectors of CSS3 for MooTools 1.2, MooTools 1.3.1, JQuery 1.5.1,
Prototype 1.7, YUI 2.8.2 Selector, and Dojo 1.5. A JavaScript Framework
should not be heavy in terms of storage as they could grow while features are
added or extended. The author considered modularity as a crucial aspect
to check for. As for other developers, the community and its activity are
important, as Walsh considered those factors as reflective of quality and
interest. The practitioner also advises to check for the kind of Web sites
which use the framework. As for any other programming language, it is
helpful to identify if the needs of the Web application will be fulfilled and if
implementation is effectively time consuming or not.
The website designzum.com offers a list of the best JavaScript Framework based on parameters such as weight in terms of code, ease of learning and implementing, modularity, simplicity of wrapping up with new features. The list appears to focus on two keywords: lightweight and simple to learn.

The website jsdb.io ranks the JavaScript Framework by exploiting four parameters coming from the GitHub repositories of the frameworks. The metrics used is composed of (1) stars, or the number of GitHub watchers, (2) the average length of time between commits, (3) the number of contributors in the last 100 commits, (4) the number of forks made for a given project.

Jster.net offers a categorization of 1573 frameworks. The catalog is divided into the following categories. Essential frameworks, UI, Multimedia, Graphics, Data, Development, Utilities and Applications.

The review of the literature and of the practitioner’s sites has suggested that scientific research has developed metrics that can be applied for the measurements and it also introduces a model which is based on subjective criteria arising from a qualitative research on the practitioners’ feedback. The practitioners, however, appear to value more practical features of a JavaScript Framework or library that are important for developers. Niche technical Web sites have adopted miscellaneous, non validated variables to rank or list JavaScript Framework. This plenitude of non scientifically validated parameters has made us research for a proposal of a model which gathers the empirical and theoretical knowledge for identifying the relevant variables that guide practitioners towards the choice of a JavaScript Framework.
3. Methodology

The present research aims to deliver new knowledge concerning the features that decision makers weight as important when selecting a JavaScript Framework. We are studying human behavior based on the perceptions that the individuals offer us. Qualitative data analysis techniques from grounded theory responded to our needs [11]. Therefore, we opted for a qualitative analysis with an interpretivist approach that uses grounded theory as analysis method. Interpretive research is often conducted when producing theories and models for explaining phenomena [12]. Researchers employ grounded theory as a methodology or as a tool for analyzing data related to human behavior [13], especially when the research has an explanatory focus [14]. We adopted Strauss and Corbin [15] proposal for grounded theory.

3.1. Participants recruitment

We planned the selection and recruitment of the participants so as to identify individuals, which could have enriched the research outcome through sharing their experiences and thoughts. Although we followed a judgmental sample strategy, we opted to sample up to reaching theoretical saturation as suggested by Strauss and Corbin [15].

The recruitment process started by finding developers who were working actively in the Web development field and who were competent, proficient and experts in Web development.

The time it takes to be proficient in a programming language is strongly dependent from the already acquired knowledge that the programmer has [16]. The model proposed by Dreyfus and Dreyfus [17], that describes the
skill acquisition, proposes these stages: (1) novice, (2) advanced beginner, (3) competent, (4) proficient and (5) expert. This model states that novice and advanced beginners have no recognition of relevance of the task they are assigned to, while competent, proficient and expert do. The first two levels of skills apply to those individuals that are not autonomous and are not able to deal with the resolution of complex situations. We expected the participants to belong to the competent, proficient and expert level of skills in the field. We expected the participants to be decision makers and to have a broader view on the technologies used for Web development and particularly JavaScript. Furthermore, we expected them to have a historical knowledge of the frameworks and their evolution over time.

Developers behind JavaScript Frameworks tend to be part of open source communities. They share their knowledge either on forums, blogs, Web pages or publications, so the recruitment phase started on the Web.

The recruitment process employed social networks as its primary source for finding candidates. We identified the hashtag ( # ) symbol and tool as a key to filtering the conglomerate of information spread over the Web. The hashtag is a form of metadata tag used in social networks such as Twitter, Facebook, and Google+. Hashtags allow the social network users to post information on a specific topic by using the same word after the symbol. That is, hashtags are tags to easily categorize posts. This allows people who search for a specific keyword to have all related posts grouped in the view.

We structured the research by keywords into three phases, all of which employed different social networks. The first one focused on the widely adopted social networks Google+, Facebook, and Twitter. The second approach was
researching for more specific figures based on their skills and knowledge in a more formal platform such as LinkedIn. The third approach consisted in researching as an insider into the community of JavaScript Framework within the social coding platform GitHub. During the first approach, we crawled the three social networks using the following hashtags: #javascript, #javascript framework, and #Web #development.

We reviewed the initial query results every 4 hours for a week. The research results returned posts of developers, help requests of novices in the field, talks from journals and posts for advertising services. We focused on the posts of developers. We inspected their profile to see the description of their working area and skills. In those cases where a Web site was included in the profile description, the Web site was checked for any additional information on the candidate that could be helpful to identify his work, current and past experience. In some occurrences the reference Web sites were blogs maintained by the candidates. We prepare an invitation text for the recruitment, which was adapted depending on whether more detailed information on the candidate could have been retrieved.

The e-mail recruitment offered a brief explanation on where the contact was retrieved from and what was the purpose of the research, without revealing details on the research question. We also specified the time commitment expected of the interviewee. In the footnotes we added the contacts, which could have been used in case of interest.

The second approach focused on a professional social network, which is LinkedIn. Here professionals complete their profile descriptions by adding skills and certifications. The recruitment here was done based upon the
skills. Candidates were recruited by sending them direct messages.

The third approach was getting into the heart of JavaScript Framework design, by analyzing GitHub repositories. Some JavaScript Framework communities were chosen based on popularity such as AngularJS, JQuery, NodeJS etc. GitHub allows to research the community for the most trending repositories and developers of the month for any of the languages in their repositories. We selected the candidates appearing in this view for the month of July 2014. We contacted them in case they provided any e-mail or company contact information.

3.2. Interview design

The qualitative research interview, especially when undertaken through an interpretive worldview, seeks to describe the world and the meaning of specific phenomena based on the perception of the participants [18]. The information retrieved during the interview stems by the experiences of the participant. The interviewer can deepen the understanding of the responses by asking additional questions as it is interactive [19].

For the research design we chose to design a semi-structured interview, and we formulated open-ended questions. This kind of interview, based also on open-ended questions allowed to briefly enter the subject of the research and to discover new information if the persons were less eloquent than expected. The starting questions are available in a digitally preserved repository\footnote{\url{http://figshare.com/s/e5a88280aac911e49f3e06ec4b8d1f61} (currently a private link for peer review process)} Over time, fifteen practitioners agreed to participate to the interview.
and three individuals participated via e-mail, up to when we agreed that we reached theoretical saturation. The interviews were conducted telephonically, personally, via Skype and Google Hangouts, and via w-mail. Interviewers were asked to respond with their availability and a time schedule appropriate for them for the interview.

We obtained either a verbal or written consent prior to recording the interview. The interviewees were informed that they could conclude the interview at any point. The participants were informed that we would not have had collected data for third parties, that the data would remain with us and the transcripts would have not been published but only the research findings. We used participant codes to identify candidates so that the responses could not be traced back to the participant’s confidential data. It was mentioned that no detailed information concerning the company they were working for would have been asked.

We expected the duration of the interview to be within five to ten minutes. This was thought to be an acceptable length as the candidates were participating during their free time. We informed them in advance that the time commitment would not impact heavily their time schedule.

3.3. Data Analysis

Following the grounded theory approach, we analyzed the data by developing codes, which are words or phrases that summarise the content of a data segment, be it a word, a sentence or a paragraph [15]. Extracts of the responses can also be a code and we refer to those as in vivo codes [15].

There are three levels of data coding as suggested by Strauss and Corbin [15], namely (1) open coding, which refers to the comparison and categoriza-
tion of data; (2) axial coding, which tries to understand relationships between categories and subcategories or other categories, attributes between codes that can be included in categories; and (3) selective coding, which refers to the process of integrating and refining the theory [15].

Codes which refer to a similar concept are grouped into a category. Categories may contain information which, if grouped, creates a relevant subject for the research question, also referred to as themes [15].

We transcribed the interviews immediately after they were concluded. Then, the coding process started so as to identify possible interview questions that could be asked to the next participants to deepen the understanding of the subject of the research and to immediately identify possible codes. We analyzed the data with the NVivo tool.

The open coding phase produced 76 codes including labels and in vivo codes. During the axial coding, the focus was on identifying categories and subcategories starting from the codes. We identified eight categories and fifteen subcategories as shown in Figure 1. The final phase of selective coding focused on identifying core variables within the categories that could cover all the codes and answer the research question. These core variables were used to recode the data according to it and to identify further parts of the transcripts which relate to them. The identified themes were: Factors theme and Actors theme.

4. Results

This section presents the results of the research. Initially, we provide a classification of the participants based on the parameters taken into consid-
eration during the recruitment phase. We present the participants through their anonymous ID, in order to refer to them in the rest of this work. Subsequently, we explain the themes (i.e., relevant subjects for the research question) that we discovered during the coding phase. Each theme collects categories and subcategories (i.e., groups of code which refer to similar concepts). Each category collects codes, most of which are accompanied by citation of transcripts’ extracts.

4.1. Participants’ classification

Eighteen participants were recruited for the purpose of this study. We contacted fifteen participants via synchronous communication (verbally) and three via asynchronous communication (e-mail). The participants were located for working purposes in the following countries: Albania, Germany, India, Italy, Netherlands, and the USA. The data was collected via a phone interview for two participants, chat via Google Hangouts for two participants, call via Skype for eleven participants and three participants requested the questions to be sent via e-mail.

The interviewees were classified according to five attributes: (1) Years of experience, (2) Framework used, (3) Development focus, (4) Company size, and (5) Company type. The results are displayed in Table 1. What follows is a description of each attribute used in the classification.

Years of experience. Participants answered the question “Since how long have you been developing for the web?” The minimum experience was 4 years and the maximum experience in the field was 15 years.
Table 1: Classification of participants

| ID | Years of experience | Framework used | Development focus | Company Size and Type |
|----|---------------------|----------------|-------------------|-----------------------|
| P01 | 4                   | Unassigned     | Front- and Back-end | Small Research        |
| P02 | 4                   | Unassigned     | Front-end         | Independent Worker    |
| P03 | 4                   | Unassigned     | Front-end         | Medium Industry       |
| P04 | 5                   | Own            | Front- and Back-end | Medium Industry       |
| P05 | 5                   | Own            | Front- and Back-end | Small Industry        |
| P06 | 6                   | Unassigned     | Front-end         | Large Industry        |
| P07 | 6                   | Unassigned     | Front-end         | Small Industry        |
| P08 | 6                   | Unassigned     | Back-end          | Large Industry        |
| P09 | 6                   | No             | Front-end         | Independent Worker    |
| P10 | 8                   | Unassigned     | Front-end         | Large Industry        |
| P11 | 8                   | Unassigned     | Back-end          | Large Industry        |
| P12 | 8                   | Unassigned     | Front- and Back-end | Medium Industry       |
| P13 | 9                   | Unassigned     | Front-end         | Medium Industry       |
| P14 | 10                  | Unassigned     | Back-end          | Medium Research       |
| P15 | 10                  | Unassigned     | Front- and Back-end | Small Industry       |
| P16 | 11                  | Unassigned     | Front-end         | Medium Industry       |
| P17 | 12                  | Unassigned     | Front- and Back-end | Medium Industry       |
| P18 | 15                  | Unassigned     | Front- and Back-end | Large Industry       |
Framework used. The participants answered the question “Do you use any frameworks for helping development?” or “Which framework do you use for developing web applications?” This classification includes three possible assignment values: (1) Using no framework; (2) Using own framework/code; (3) Not applicable in case none of the first two options applies. The need for this classification arose from the fact that one of the participants stated to not use any framework for developing: “I don’t rely or use any framework, except cases when client requires it [...] I prefer JavaScript. It seems more natural to work with the language than library.”—P09.

Two participants stated as follows:

“I decided to create it on my own, I created some classes which interact with the underlying system. The framework will be soon also available for download. I will distribute it under GPL license, for non commercial and for commercial use.”—P05

[referring to a former statement of the interview that JQuery according to people is fantastic] “not now, although it helps me greatly expand the idea of what people need even make your job easier, because i did my own framework”—P04

Development focus. The participants stated if they were working for the front-end or for the back-end or for both. Three of the participants were working exclusively in the back-end, six of them stated they were working on both the front and the back-end, while the rest of the participants stated to be working mostly or exclusively in the front-end.

Company size and type. While two of the participants stated to be working on their own, five of them were working in large business companies, seven
interviewees were working for medium sized companies and four of the participants were working for small companies with a maximum of 5 collaborators. The majority of the developers work for companies which have IT as their core business while the others work in different areas such as industry (sales, outsourcing, finance) and research. This information was collected in the form of memos during the participant recruitment phase.

4.2. Themes for the Factors

The Factors theme groups the attributes of a JavaScript Framework according to a set of categories of features. Categories and subcategories extrapolated during the coding phase can be observed in the first half of Figure 1.

4.2.1. Usability

Usability summarises those attributes of a framework that make programmers achieve their goals and make them feel confident, efficient and effective if using it. It also refers to the capacity of a framework to be attractive and understandable by developers. This category comprises these subcategories: (1) Attractiveness, (2) Learnability, and (3) Understandability.

Attractiveness. Describes mainly what raises the interest of developers towards a JavaScript Framework.

“People were always talking about the fantastic JQuery”—P04

Programmers consider as valuable the age of a framework:

“I think AngularJS is a mature framework also because of its age probably because it is the oldest framework which is around. It took years to get popular and now in these years it took off.”—P12

19
Figure 1: A Model For Javascript Frameworks Adoption Decision-Making
They get curious about new frameworks while researching the technical blogs, companies that already use the same framework, and search engines.

“There were blogs which did comparisons on both the ease of use and the completeness of the arguments covered by the framework.”—P07

“We have also done some research on the market: how many companies, if there are other companies in similar context which are using Angular. And we found quite a lot of those.”—P12

When talking about attractiveness and the popularity of the JavaScript Framework, the participants often mentioned the communities behind the development of the frameworks. We developed two codes related to the community, namely responsiveness and size. Developers try to identify products that are expected to be used in the long term and that are ameliorating continuously.

“Communities are quite important we rely on them every time and as much big the community as faster you receive responses from them. [...] When querying a community of open source for such big projects such as AngularJS it is easy that you receive a fast response very easily in few time.”—P01

“Every framework with time gets mature when many people around the world try their hands in that.”—P08

The community is the heart of an open source project as it is a container for new ideas to extend product functionalities, and bug fixes. The larger the community, the faster the response time in issue resolution.

Finally, attractiveness is also proxied by a perceived reduction of complexity: Interviewer: “What do you mean by benefit? Is it in terms of a
specific quality that they satisfy?” P01: “We want to avoid complex systems and we want libraries to integrate with what we already have.”

**Learnability.** Reflects the effort that a developer should make to learn the framework. The requirements for starting to use a framework can be high or low but this depends also on the technical skills of the developer. Some participants admitted that they choose the framework and libraries according to the time they are given to submit the project.

“Most of the time you search for plugins to do something small and there you do not have to learn. You just check if it does what you need it to do. Otherwise, let’s for instance refer to AngularJS it would take some weeks to learn the basics.”—P03

**Understandability.** Comprises the attributes of software that allow users to recognize how the JavaScript Framework can be applied and used.

A well documented framework allows to save time and to extend the functionalities coming with the base source code faster.

“You also check the documentation if you want to do something which is not already available in the examples. Meaning, if you want to do something more extravagant.”—P03

A framework with a clear code structure contributes in shortening the time a programmer becomes familiar with the new platform.

“I got interested in AngularJS because of the two way data binding, and clean and easy to comprehend structure of the code. It is easy to become productive quite fast with this framework.”—P02

Programmers tend to search the documentation to find already backed solutions that help to structure the application.
“It has a lot of helper models to make our life easy. So that’s about what we want. If we want some helper function to rewrite some of our code.”—P13

“The web services are usually in Rest and also for Rest the MVC Framework of Spring is very easy to use. They are a couple of methods and annotations, which make it very easy.”—P14

The programmers who are using pure JavaScript for developing stated that even if using frameworks shortens the development time, the developer should have sufficient knowledge of JavaScript:

“I would advise anyone and everyone to think independent of frameworks, and languages. It’s paradigms, and patterns that matter.”—P16

“Generally I was always more into pure JavaScript. I started with it and fell in love with it. In project it is more likely switched ... I start with pure JavaScript to do the basic and necessary stuff and then use framework or lib.”—P09

4.2.2. Cost

Five of the participants stated that they try to use mostly free frameworks. The participants stated that this depends on the customer’s requirement to keep the costs low:

“If something [referring to frameworks and libraries] is not free then we see how much it costs, if it is bearable for the company and plus what functionality it is providing to us.”—P13

“The libraries we use are chosen first of all in the open source environment. The customers prefer projects which are composed of many open source components.”—P15

The developers motivated the choice either as coming from a company’s
strategy or as coming from the customer’s requirements.

“I proposed the change due to the fact that we have to go open source” — P12

4.2.3. Efficiency

Efficiency is tested according to the performance of the application in terms of running speed and hardware resources used.

Performance. The programmers explained their concern on the overall per-
formance of the final application and on its size. They described as a draw-
back the case when the number of lines of code to build basic functionality is too high or when the payload for including the required functionality is too high in terms of memory and bandwidth. A participant stated the following in regard.

“[making a decision] may also be related to the requirement that you ac-
tually have. Like using React right now seems to promise a lot of performance benefits [...] to the hardware side” — P10

“Google [PageSpeed Insights] measures all the cache timing, cookies, it measures and tells you if this JavaScript weights too much and it tells you to optimize it and thats why we use Less. We have been using Less a lot recently.” — P06

Size. The size application developed via a JavaScript Framework is used as a parameter for evaluating new frameworks to use:

“I developed a small demo prototype to see how it [the framework] actually is practical, so how much code it produces for example.” — P12
“[referring to CodeIgniter] It creates too many unnecessary files which create a packet that is too heavy for smartphones [to process]” —P05

4.2.4. Functionality

The functionality category includes the set of attributes that satisfy the needs of programmers: (1) Automatisation, (2) Extensibility, (3) Flexibility, (4) Server isolation, (5) Modularity, (6) Suitability, and (7) Updates.

Automatisation. Refers to those cases in which developers appreciate those frameworks that have code for automatizing the development of given functionalities, such as DOM manipulation, data handling, real-time update of visualizations.

“AngularJS because [...] allows you to bind your data to the application and you do not have to program anything. It does everything automatically and you do not have to add anything and it is very easy to use from that point of view. I had used it to create some forms where you could add some fields dynamically.” —P13

Extensibility. Pointed out by a programmer when talking about issues in extending frameworks:

“Let’s say it is easier to use [Angular] but more difficult to extend. Let’s say there are other frameworks which are more difficult to use but then are more extensible.” —P03

Flexibility. Mentioned by four participants, with the addition that it might cause lack of modularity.

“As far as I know there is no really good approach for modularity in the application. So if you have, if you want to implement some more advanced
features like lazy loading of modules and that stuff you have to do it on your own. [...] AngularJS allows importing external libraries because most of the parts are based on JQuery, however you have to wrap those into Angular directives. So that’s for sure one disadvantage of Angular. [...] you cannot simply take a JQuery plugin for instance and put it into the project. You could, but it is not suggested by the Angular team. You have to wrap it such that you can augment those plugins by augmenting the initial HTML code basically. So through those Angular directives. That’s how they call it.”—P12

Isolation. The participants admitted that they tend to develop applications that exploit the client as much as possible instead of the server. This design strategy is done to preserve the server status.

“We want to touch the server as little as possible” and to keep the application mostly on the client side, that’s why we put bunch of code that creates the page without touching the server side and so the page is updated only by the engine of JavaScript”. —P17

Modularity. One of the developers who was not using any framework for developing, but was integrating libraries into pure JavaScript code, admitted that the principle of modularity does not apply when using your own code as sometimes issues of compatibility can occur:

Interviewer: “Did it ever happen that they did not fully integrate with what you were developing?” P09: “You bet. This is not so rare. Sometime, I have to look around and implement another one library or to hack and modify the source code.”
The developer who had built his own framework instead pointed out that the need of extensibility and modularity in sense of scalability were crucial, that was the reason he programmed a new framework for JavaScript.

“The framework is composed of different libraries, allowing scalability and also allows users to use their own libraries, making them part of the core system [...] It allows to change one module without affecting the others.”—P04

**Suitability.** Collects the attributes which evaluate if the product is appropriate for fulfilling the tasks required in a specific function.

One of the front-end programmers admitted that what is done while searching for a library or a function is what problem it is solving; while several others pointed out that nowadays libraries are commonly included in the native libraries of a framework.

“If I go for Knockout JavaScript if I want to go for HTTP connectivity I will check if JQuery has something but when you take AngularJS it has it’s own library to do that.”—P13

A framework which can create a complete application fulfilling the expectations of the developer gains advantage over others; it is seen as a good solution for saving time and avoiding exhaustive search for the suitable library.

“[referring to Dojo Toolkit] I chose this framework because I needed something which could create complete applications and something that could handle the chaos that was by that time of the JavaScript libraries and this framework does both of these things in a descent way.”—P11

Programmers evaluate tools and frameworks over time and according to
tasks and needs. They can make proposals to their team leader (or the rest of the team in case of self-organized teams). The team leader (the team) analyzes the request to identify how it could possibly integrate to the project. If the integration is feasible, the leader (team) accepts the request or identifies already provided libraries, which can achieve the desired functionalities.

P07: “If there is something particularly useful [...] and] if it implements something interesting they [the frameworks] are inserted in the project. Then they [team leaders] organize tech talks to teach how to use the new added libraries.”

Interviewer: “During the tech talks do you discuss about the structure of a library, functionalities or what else?”

P07: “Yes, for instance I needed to use PowerMojito which is an extension of Mojito. I would go to the Ambassador which takes care of the test section. If I go there and tell him that using it has this and that advantages, he can decide to insert it in the libraries which are imported by default. He then decides to arrange tech talks, during which they talk about the functionalities and why it is useful and how to use it.”

The framework should not only be suitable to achieve a requirement, it should also be suitable for the programmer. A developer stated that he appreciates also the architecture of the framework as it allows him to have continuous control and full visibility of the structure, and this is one of his needs.

“I am more and more moving toward React because it is solving the problems in a more elegant way, in my opinion. So organising the rendering strategy between all your components and parts of the application is way
more organized if you use React.”—P10

*Updates.* Describes the need of developers to use frameworks which are continuously updating and extending their functionalities to stay competitive in the market we chose the subcategory of updates.

“The issue was that MooTools did not have a continuous evolution and had a lot of bugs and issues with different browsers.”—P06

“And then AngularJS is more modern let’s say. So it has some features which Java MVC didn’t have or doesn’t yet have.”—P12

4.3. *Themes for the Actors*

The themes for the *Actors* refer to how the developers decide which framework to proceed with or which library to include during the development. The categories that we identified are displayed in the second half of Figure 1.

Developers admitted to base the solution on the customer’s decision in case they had to work on already existing projects or to choose freely according to the parameters presented in the previous themes. It was interesting for the purpose of the research to explore the decision process of teams. How do teams choose a library? Who decides? Two categories arose: decisions made as a team and decisions made by the team leader.

Teams choose different strategies for evaluating frameworks. “We took an existing set of pages and rebuilt them using Angular and what we looked at was the amount of effort involved and how easily testable it was. We check in team the libraries which could work good for solving an issue and we meet and talk, as the community is quite big and it evolves quickly. We choose
the one library which could bring us more benefit. Nothing is rushed because there is too much out there.”—P18

“We have a team that researches and then we propose the solutions to the others so that each one can say his opinion. We state the characteristics of each and then we discuss which one to pick.”—P01

“If there is something particularly useful which is not being covered by the libraries, which have already been imported, we can talk to the Ambassador of the area, in this case for example the Test Ambassador. You show him the plus and minus. If you need something else, for instance recently, I needed the framework we use for doing tests. The one we use to create MOCs.”—P07

4.4. Summary of results

Programmers prefer free frameworks. Web pages created through frameworks should run fast and should not be too heavy for the client. The size and the verbosity are measured in terms of lines of code the framework generates, and developers want to optimize both of them.

A framework should help to (1) organize and (2) to structure the application, but it should always allow maintaining the overview of all the components involved and of the execution flow. If these two factors are missing the complexity of the development is expected to increase.

Developers expect that some basic activities such as data binding, DOM manipulation, and real time update of the application are present. The existing libraries and functionalities of the framework should allow modifications via simple operations such as override. The framework should be modular in the sense that if a part of the code is changed it will not compromise the overall application. The JavaScript Framework should also integrate with
the already existing infrastructure. If the programmer sees that adding or extending features requires more effort than expected they will not choose that framework. Importing external libraries easily in a framework is also a requirement. Some developers find that having to wrap the libraries with additional code for making them importable could be a drawback. The design strategy of keeping the application on the client side or not should be accomplished easily.

Programmers check which functionalities are already implemented in the framework for doing simple and advanced tasks. While choosing a library or a framework they check what problem it is solving by reading the documentation provided by the library. Frameworks that are up-to-date with the technology trends (new browsers, new Web design trends) are preferred. A good framework should be easy to use and in continuous evolution to accommodate customers and developers requirements.

We identified three approaches to the process of searching for a framework: (1) inserting the query of their requirement in search engines such as Google and checking the results, (2) reading user reviews in blogs or Web sites such as Reddit, (3) researching the market so as to identify other companies operating in the same field that have been implementing frameworks. The analysis of a framework consists principally in (1) checking the age of the framework and (2) the size of the community behind it. The size of the community is an indicator of a fast response time in case of bug fixing, and it also means that the framework is evolving thanks to the contributors. The age of the framework, according to developers, is a signal of stability and maturity. If it has been around for a long time it means that several experts
have assessed it as valid to maintain and extend.

The code of the framework should be easily understandable and it is important that the documentation provides examples or suggests tools which can speed up development. Both these factors help developers to estimate the time it would require them to become proficient in the usage of a framework. The easier the syntax of the framework the more attractive it is.

Teams choose “in team” so they try prototypes, they rebuild a page with different frameworks, they analyze already existing sets of pages, they create their own benchmarks for analyzing frameworks which include the check for: amount of effort involved in learning the language and how easily testable it is. In more structured teams with a predefined hierarchy they prepare a Model of Computation (MOC) or a Proof of Concept (POC).

5. Discussion

This section discusses the obtained results. First, we compare our results to the related work. An overview of this research work, including the research question statement, the analysis of the already existing works in the field and the results of this research. We discuss the findings and present their pertinence with respect to the research question.

We identified three related works. The first two papers [7, 6], focused on measuring the quality, performance, maintainability and complexity through metrics. The authors analyzed the Lines of Code (LOC) the Cyclomatic Complexity (CC), etc. by means of formulas or already existing tools for software measurement. The third paper [5] suggested extensions to the categories proposed by the first work of Gizas et al. [6] by suggesting focus on:
Our findings confirm that the size of a framework, as suggested by Misra and Cafer [7] and Gizas et. al [6], is important for practitioners, but it is not sufficient alone as a metrics. Practitioners care to understand the payload brought by frameworks in the context of their own Web applications as well. For this purpose developers implement ad-hoc benchmarks to measure the number of lines of code generated for a sample Web page or a sample application. The performance of the framework measured in terms of execution time, as introduced by Gizas et. al [6] and Misra and Cafer [7], is confirmed to be a factor influencing the choice of a JavaScript Framework.

This research corroborates the statement published in the paper of Graziotin and Abrahamsson [5] that programmers study the documentation, to evaluate the time they would need to be productive. More specifically developers tend to prefer frameworks that include examples of achieving simple tasks and hints for achieving advanced functionalities.

The findings of this work support the classification of a frameworks maturity introduced by Graziotin and Abrahamsson [5], based upon the frequency of released updates. This classification is extended by adding the frameworks’ age parameter. This parameter was also mentioned as an important factor by the technical blogger J. Reyes [9].

A JavaScript Framework, as mentioned in the technical blog of J. Bennet [8], should be accurate and represent the language as it is. This, according to our findings, can be achieved if the framework allows developers to have an overview of the execution flow of applications. Developers like to understand how the framework operates in order to promptly identify possible issues.
Our results confirm that modularity, as J.Bennet [8] reported, is a factor that plays a significant role in the choice of the framework. Modular frameworks ease the process of modification of code sections without affecting other components. Our findings match the statement of D. Walsh [10]: a framework should be suitable for achieving the functionality it addresses. Furthermore, programmers like frameworks which include libraries for achieving basic and advanced functionalities in their core version.

This research outlines the factors which influence the choice of a JavaScript Framework, namely usability (attractiveness, learnability, understandability), cost, efficiency (performance, size), and functionality (automatisation, extensibility, flexibility, isolation, modularity, suitability, updated). These factors are evaluated by a combination of four possible decision makers, that are customer, developer, team, and team leader.

5.1. Implications

This research outlines a number of practical implications regarding the consideration of JavaScript Framework. They are outlined below:

- The number of lines of code of the applications created by means of the framework should be preferably low.

- The size of the package containing the application should be as minimal as possible, as a big size could be not suitable for smartphones.

- The code of the framework should be easy to read.

- The framework should be modular; changing a module should not affect others.
• Simple tasks such as event handling, DOM manipulation, and real time component update should be automatized.

• The application created by a framework should run in different browsers.

• The libraries that come with the framework should allow to achieve basic and advanced functionalities.

• The framework should allow to import external libraries without having to adapt them.

• Free frameworks are preferred compared to paid ones

• The framework should state clearly if it is intended for developing applications that will run relying mostly on the resources of the client or on those of the server.

• Frequently updating the framework with new features for matching the Web design trends is evaluated positively.

• The documentation should be precise and include several examples for implementing common tasks. It should allow developers to find quickly guidelines on implementing a feature.

• The community behind the framework is its heart and as such its size and contributors signal the trust of developers in the technology.

• Frameworks which have been around for a longer time are preferred to new ones.
• A framework is estimated as reliable if it is being used by other companies in the production environment.

The outcome of this study aims to be a guideline for developers who wish to select a framework that fits their requirements or those of the customer. The model that we propose can be used as a reference to evaluate new JavaScript Framework or to confirm the choice of the already chosen ones.

Our model can be inspiring for those developers willing to publish new frameworks so as to make them captivating. The variables introduced by the model reflect the thoughts and expectations of practitioners which have a broad view on the portfolio of JavaScript Framework in the market. The development of a new framework could thus try to observe these recommendations so as to gain popularity with respect to already existing ones.

This research, enriched the on-field scientific work by identifying additional attributes that are relevant in the choice of a JavaScript Framework such as: the native support for basic and advanced features, the compatibility with existing infrastructures, the possibility to choose if the application should run mostly on the client or on the server side, and its cost. This can lead to further quantitative and qualitative research on these factors.

5.2. Limitations

The most significant limitation of this research to be mentioned is that the sample is judgmental and limited in its size. Eighteen participants were recruited using predefined criteria. While random sampling might appear to be preferable for research activities, this research was able to reach a theoretical saturation as suggested by grounded theory methodology [20].
Additionally, the sample size lies in the range of the suggested number of participants in qualitative studies [21].

A minor limitation of this study lies in the fact that the interviews were done mostly using Skype, Google Hangouts or telephonically. This kind of communication differs from the face-to-face interview. The environment typically chosen for the interviews done in person would have allowed to focus also on the emotions and mimics of the interviewees. Conversely, the participants are all familiar with these instant messaging and conferencing technologies and feel more comfortable if they choose the time and the location for the interview. Besides this, as the participants who were recruited work in different countries it would have been economically unfeasible to arrange in person interviews with all of them.

6. Conclusions

The proliferation and diversity of JavaScript Framework has made it difficult for both novices and experienced programmers to identify the patterns they should take into consideration for choosing a framework. Furthermore, developers who wish to release new frameworks require an overview of the most relevant characteristics that a framework must assure to guarantee its adoption.

This present research identifies a lack of research for solving the previously reported issues. Existing research is mainly focused in predefined metrics which have been reported to have little meaning for practitioners. While benchmarks, technical reports, and expert’s opinions are available, they suffer the same problem identified on the scientific research field. The knowledge we
were missing concerned the processes and the reasons that drive developers towards the choice.

The purpose of this study was to identify and understand the human factors that influence the choice of a JavaScript Framework with respect to another. This research reported a qualitative interpretive study based on grounded theory, which we conducted by interviewing eighteen participants who are decision makers in their companies or on their own, or are able to motivate the JavaScript Framework decision process.

Therefore, the research aimed to answer the research question “What leads developers towards the choice of a JavaScript Framework?” The research question was answered by presenting: (1) a model of features that are desirable to be found in a JavaScript Framework; (2) a representation of the decision makers involved in the frameworks selection, which sets the context and scope when employing the model in (1).

This work confirmed the factors which were already discovered in previous research. However, the findings of this research empirically demonstrate that those factors were only the tip of the iceberg for understanding the human decision processes. Moreover, several variables discovered by previous research were shown to be assessed in ways that are not meaningful for practitioners. Finally, this work extended the existing body of knowledge by introducing new factors at the macro-level and at the micro-level.

Our work lies down foundations for future research. Quantitative studies can be conducted in order to employ or develop metrics per each of the discovered attributes identified in the themes. These future works should lead towards the creation of benchmarks that have real, practical utility.
Altogether, we envision the creation of a global ranking system of JavaScript Framework which will be valued by the practitioners.

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