Mobile application development process: A practical experience

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Abstract — **Nowadays there is an increasing interest in mobile application development. However, developers often disregard, or at least significantly adapt, existing software development processes to suit their purpose, given the existing specific constraints. Such adjustments can introduce variations and new trends in existing processes that in many occasions are not shared with the scientific community since there is no official documentation, thus justifying further research. In this paper, we present a study and characterization of current mobile application development processes based on a practical experience. We consider a set of real case studies to investigate the current development processes for mobile applications used by software development companies, as well as by independent developers. The result of the present study is the identification of mobile software development processes, namely agile approaches, and also of shortcomings in current methodologies applied in industry and academy, namely the lack of informed and experienced resources to develop mobile apps.**

Keywords – Mobile application development; SW engineering.

I. INTRODUCTION

Currently, millions of apps are available in different online stores to smartphone users. The most successful mobile applications have been downloaded over a billion times [1] and each day new applications are launched to the mobile market, making it extremely attractive both for companies and indie developers to invest their time and money. Such demand has often led mobile software (SW) developers to adapt established SW development methodologies or submit new proposals that fit the constraints related to mobile SW development.

The mobile SW development particularities are diverse, but surely include short and frequent development cycles, frequent technological changes (platforms, operating systems, sensors, etc.), limited documentation, specific requirements and resources of the development team and the client, among others. In addition, all these possible factors are prone to constant innovation [2].

The steps being taken to develop mobile applications may differ depending on the project or established technologies. Mobile apps are the result of several activities that are carried out, such as, assigning roles to the work group, defining objectives and activities, implementing a set of good practices for teamwork and collaboration, establishing the schedule of activities, risk management, among others. In the end, guidelines must be adapted according to available resources and customer requirements [3] [4]. Furthermore, mobile application development requires continuous improvements and adaptations to meet new technological needs and changes, presenting significant challenges such as: design of user interfaces for different sizes of screens of mobile devices, user experience linked to capabilities of mobile devices, user interaction methods provided by mobile platforms, architectures, among others [5].

This need for speed of adaptability is one of the causes for the limited formal and scientific documentation in the field of mobile application development. At present, there is a lack of scientific documentation that reflects development processes focused on mobile applications and their activities [6].

SW-level mobile application development processes are not fully established by today's industry. The objective of this research is to better understand the current methodologies adopted, to identify which and how processes or methodologies relevant to the development of mobile applications are carried out in two contexts: academic and industry, counting for the latter with case studies in small, medium and large Ecuadorian and Mexican companies. This study also contributes to better understand mobile application development processes, examining the real challenges faced, the activities carried out, and considering the characteristics of the development team using real case scenarios.

The rest of the paper is organized as follows. Section II addresses related work, while Section III sets out the applied research method. Section IV presents the results obtained based on the research sub-questions raised and, in Section V, the discussion of the results is present. Finally, Section VI presents the conclusions and future lines of research.

II. RELATED WORK

In this section, we present the works that have addressed the challenges related to the study of current mobile application development processes.

Using first-degree techniques to collect data, researchers have identified issues or challenges in mobile SW development. Flora et al. [6] investigate the challenges faced during mobile application development processes through a survey of the mobile research and development community. Some business restrict their focus to a single platform which reduces the reach of their applications, few participants expressed concern about the lack of informed and experienced

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resources to develop mobile apps, assessing the effort required at the beginning of the cycle and note developer team spend a lot of time understanding and analyzing customer's requirements increasing their workload with developing, integrating and testing the apps [6]. On another view, Wasserman [8] through a survey for mobile app developers, concluded that most mobile apps are relatively small, with one or two developers responsible for designing and implementing the whole application, rarely using formal development processes and with very little development follow-up, under few metrics. Additionally, several studies agree that most mobile application developers use agile approaches or almost ad-hoc approaches, given the fact that, as mobile phones are evolving so quickly, short development and planning time is required and development cycles may be the way [6] [7].

SW engineering of mobile applications has a strong emphasis on User Interface (UI) design. Flora et al. [6] establish that mobile developers find it challenging to make best possible use of limited screen space, and UI design takes on greater importance than ever. This fact is related to the User Experience (UX), where the developers indicate that a smaller display, screen layouts and different user interaction styles have major impact in designing a mobile apps, eventually resulting in low adoption and usage of the application [6]. Even though developers can control most aspects of the UX, mobile applications often share common elements of the UI with other applications and must therefore adhere to externally developed UI guidelines, many of which are implemented in software development kits that are part of the platform [8]. Additionally, mobile application developers must anticipate the targeted devices for UI design. Specifically, if targeting a single platform, developers may decide to build a single application for all platforms at the risk of some functional inconsistencies or instead consider building multiple version targeting each hardware platform [7].

Furthermore, in [8] it is concluded that despite the existence of a huge number of mobile applications today, mobile SW development processes are not fully adapted to mobile application development projects and they are complex to follow, since characteristics of mobile applications in their operating and real environments derive a new set of research topics with different approaches.

Current approaches present generic surveys that usually do not focus in a specific application development, resulting in relatively abstract interpretations. In the following, we present a research methodology that allows the analysis of specific mobile applications in small, medium and large Ecuadorian and Mexican companies, in two contexts: academic and industry.

III. METHODOLOGY

To describe the scenario and identify processes of mobile SW developing in practice, we propose a case study following the guidelines by Runeson et al. in [9], with the objective of identifying and characterizing the processes and methodologies in mobile application development that are currently applied in academy and industry.

We start by introducing the research questions and then the possible answers that were defined.

A. Research question

Given the above objective, the following research question has been established: "How are mobile application development processes carried out in academy and industry?" Given the general standpoint of the question, it is necessary to resort to research sub-questions, in order to achieve results that are more tangible:

- Q1. Which are the development platforms that industry and academia most frequently choose?
- Q2. What kind of mobile applications does industry and academia develop?
- Q3. What kind of companies develop SW in our scenario?
- Q4. What types of SW development processes are applied by industry and academia?
- Q5. Which specific development processes or methodologies are applied?
- Q6. Which are the specific activities that conform the methodologies or processes applied by the industry and academia for the development of mobile applications?
- Q7. What is the experience level of the development team in industry and academy?
- Q8. What period is required for the development of mobile applications?
- Q9. At what level of rigor are applied the methodologies or processes of mobile application development in the industry and academia?
- Q10. Which issues appear during the process of mobile applications development in the industry and academy?

The study is presented in two contexts, using a multiple-case design composed of two single embedded studies [10], [9], as shown in Figure 1. The first single study contains three Units of Analysis (UA) that correspond to the development processes that are applied in the academic field. Students of computer engineering of the *"Universidad Politécnica de Madrid"* develop the first two cases and the third is an application developed by students of engineering in systems of the "*Escuela Politécnica Nacional de Quito*". On the other hand, the second single study corresponds to the development processes that apply five industries. The industries considered are Ecuadorian companies, with the special feature of Arca Continental, which as a multinational, presents its mobile app development area in Mexico and maintenance in Ecuador.

Kruger Corporation (http://www.krugercorporation.com), Sofya Systems S.A. and Devsu SW (http://devsu.com/) have as their main activity the development of SW, while Arca Continental (http://www.arcacontal.com) is a company that does not correspond to the SW sector, but has a SW development provider and department that generate their applications. These industries were chosen given the openness they had to the study.

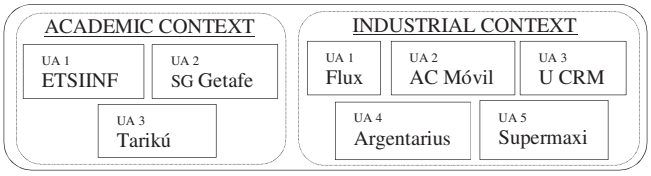

Figure 1.Units of Analysis: Mobile Application names

B. Data collection method and selection strategy

For data collection, first-degree techniques [11] are used, such as interviews and questionnaires, which allow direct contact with information sources. For information collection, a questionnaire was defined for each single study with open and closed questions that attempt to answer the research sub-questions. In addition, personal interviews were conducted with each development group leader to validate the information.

The information collected has been organized according to the sub-questions. The strategy applied is based on providing a set of possible answers to each of the research questions, as presented in Table 1.

TABLE 1. POSSIBLE ANSWERS FOR THE RESEARCH SUB-QUESTIONS

RQ	Answer options	Observations
Q1	IOS, Android, Windows Phone, others	None
Q2	Native App, Web app, Hybrid App	None
Q3	Microenterprise, Small company, medium company, large company	According to [12]: (e= employees) Microenterprise: 1-9 e. Small company: 10-49 e. Medium company: 50-199 e. Large company: >= 200 e.
Q4	Agile, Not Agile	
Q5	Process / Method/ Methodology name	If no name is reported it is classified as AD-HOC
Q6	Process activities	List of process activities
Q7	No experience, Novice, Intermediate, Expert	According to [13]: (y= years of work) No experience: 1-2 y, Novice: 2-5 y. Intermediate: 5-10 y, Expert: > 10 y.
Q8	(m= months) 1-3 m, 3-6 m, 6-12 m, more than 12 m.	None
Q9	Low, Medium, High	Low: 0-3, Medium:4-6 ,High: 7-10
Q10	Issues of development processes	Description of issues identified during the development process.

IV. RESULTS

This section presents the results obtained from the case studies, organized according to the research sub-questions.

Q1. Development Platforms

As presented in Table 2, 3 UA (1 from academy, 2 from industry) include applications that are developed only for Android. The remaining five UA (2 from academy, 3 from industries) have developed the mobile applications for Android and iOS. Finally, there is no UA in the case study that includes only iOS development.

Q2. Mobile Applications Types

Table 3 shows that 5 UA (2 from academy, 3 from industry) developed native mobile applications. One of the UA (industry) regards a mobile web application and three UA (1 from industry, 1 from academy) have developed hybrid mobile applications.

TABLE 2. DEVELOPMENT PLATFORMS: UNITS OF ANALYSIS

	University / Industry	App Name	Platform		Device		
			iOS	*Android*	*Phone*	*Tablet*	*HH*
Academy	UPM	ETSIINF	X	X	X	X	
	UPM	SG Getafe		X		X	
	EPN	TARIKÚ	X	X	X		
Industry	Kruger Corporation	FLUX	X	X	X	X	
	Arca Continental	ACMovil		X	X		X
	Sofya Systems S.A	Argentarius	X	X	X		
	Devsu SW	Supermaxi	X	X	X	X	
	Riverminds	UNIDAL CRM		X	X		

TABLE 3. MOBILE APPLICATIONS TYPES: UNITS OF ANALYSIS

	University / Industry	App Name	Mobile Application Type		
			Native	*Web*	*Hybrid*
Academy	UPM	ETSIINF	X		
	UPM	SG Getafe			X
	EPN	TARIKÚ	X		
Industry	Kruger Corporation	FLUX	X		
	Arca Continental	ACMovil	X		
	Sofya Systems S.A	Argentarius			X
	Devsu SW	Supermaxi	X		
	Riverminds	UNIDAL CRM		X	

Q3. Types of Companies Developing Apps in our scenario

According to the scale in [12], 20% (1 UA) is constituted as microenterprise being only Riverminds part of this with 7 employees. The 40% (2 UA) are small companies, being part of this figure, Sofya Systems SA: 12 employees, and Devsu SW: 20 employees. The remaining 40% (2 UA) are large companies, with Arca Continental: more than 4768 employees, and Kruger Corporation: 248 employees (See Table 8).

Q4. Types of SW Development Processes

The units of analysis (UA) are divided according to two types of SW development process: agile and not agile, with each of its methodologies or processes (Table 4). Notice that the companies generally opted for agile methodologies.

TABLE 4. TYPES OF SW DEVELOPMENT PROCESS: UNITS OF ANALYSIS

	University / Industry	App Name	Type of SW Development Process		SW Development Process / Methodology
			Agile	*No Agile*	
Academy	UPM	ETSIINF		X	WATERFALL
	UPM	SG Getafe		X	ADHOC
	EPN	TARIKÚ	X		ADHOC
Industry	Kruger Corporation	FLUX	X		SCRUM
	Arca Continental	ACMovil	X		SCRUM
	Sofya Systems S.A	Argentarius	X		XP
	Devsu SW	Supermaxi	X		SCRUM
	Riverminds	UNIDAL CRM	X		ADHOC

Q5. Processes, Methods and Methodologies applied

One UA, Argentarius app, uses XP principles as methodology. In addition, one UA presents a lightened model of waterfall method for the development of ETSIINF UPM app. Three UA applied Scrum methodology: Flux app, ACMovil app and Supermaxi app. Finally, remaining three UA, SG Getafe app, Tarikú app and Riverminds app, having no specific or named methodology adopted the term ADHOC; this does not mean that it is the same methodology or activities. (See table 5)

Q6. Concrete process / methodology activities

The concrete development activities applied in the apps are shown in the Table 5.

TABLE 5. PROCESS/METHODOLOGIES ACTIVITIES: ACADEMY UA

APP NAME	Q5	ACTIVITIES
SG Getafe app	ADHOC	1. List of requirements. 2. Design and implementation of database. 3. Deployment of the server. 4. Android Client Deployment. 5. Usability planning. 6. Usability tests with the hospital. 7. Documentation of the project carried out.
ETSIINF UPM app	WATERFALL	1. Requirements. 2. Design. 3. Implementation. 4. Verification. 5. Maintenance.
TARIKÚ app	ADHOC	1. Requirements analysis. 2. UI Design. 3. Pilot app development. 4. Unit tests. 5. Error correction. 6. Piloting process: product used by inhabitants of the area.
Argentarius app	XP	1. Specification of requirements. 2. Process Flow. 3. Design of graphical user interfaces. 4. Simplification of interfaces and application of User Experience Design (UX). 5. Construction (backend and frontend). 6. Tests. 7. Implantation.
FLUX app	SCRUM	1. Iteration Planning (Sprint Planning). 2. Execution of iteration (Sprint). 3. Daily Team Synchronization Meeting (Scrum Daily Meeting). 4. Demonstration of completed requirements (Sprint Review). 5. Retrospective (Sprint Retrospective). 6. Refinement of the list of requirements and changes in the project.
Supermaxi app	SCRUM	1. Iteration Planning (Sprint Planning). 2. Execution of iteration (Sprint). 3. Daily Team Synchronization Meeting (Scrum Daily Meeting). 4. Demonstration of completed requirements (Sprint Review). 5. Retrospective (Sprint Retrospective). 6. Refinement of the list of requirements and changes in the project.
ACMovil app	SCRUM	1. The idea of an actor (Product Owner) born. 2. The Product Owner describes in "User Stories" the desired functionality in the system (no technical language). 3. Sprint Planning (Scrum Master, Development Team, and Product Owner) Priority is assigned to the functional requirements. Tasks are performed. 4. Sprint. The time is estimated (less than 15 days) to perform a set of tasks to develop. During the Sprint, there is a daily meeting (15 min.). 5. Sprint Review. Consolidate the tasks that were completed and the obstacles during the execution of the tasks. 6. Sprint Retrospective (Scrum Master, Development Team) Meeting to achieve continuous improvement. 7. Restarting "Sprint Planning".
UNIDAL CRM app	ADHOC	1. Make views of the application in HTML5 on PHONEGAP. 2. Perform the development of C # language controls. 3. Compile the application on PHONE GAP. 4. Run the testing and debugging process in the mobile phone.

Q7. Respondent of the Development Team Experience Level

Given the scale in [13], in 4 UA (1 industrial, 3 academics), the respondent of the development team has not experience, the developers only have one year of work. In the remaining four academics UA, the respondent of the developer team is qualified as novice, with developers between 2 to 5 years of work.

TABLE 6. RESPONDENT OF THE DEVELOPMENT TEAM EXPERIENCE LEVEL: UA

Case Study Classification	Mobile Application		Years of work	Experience level
ACADEMY	SG Getafe app		1	No Experience
	ETSIINF UPM app		1	No Experience
	TARIKÚ app		1,5	No Experience
INDUSTRY	Argentarius app	Sofya Systems	1	No Experience
	FLUX app	Kruger Corp.	4	Novice
	Supermaxi app	Devsu SW	4	Novice
	UNIDAL CRM app	Riverminds	3	Novice
	ACMovil app	Arca Continental	3	Novice

Q8. Development time

One UA (industrial), Riverminds developed the mobile application UNIDAL CRM in a period of 3-6 months. Five UA (2 industrials, 3 academics) developed the mobile application in a period of 6-12 months. Finally, two UA (industrials) developed the mobile application over a period of more than 12 months.

TABLE 7. TIME OF DEVELOPMENT AND TYPES OF COMPANIES DEVELOPING APPS.

Case Study Classification	Mobile Application		Time for app development (months)	Types of Companies developing apps
ACADEMY	SG Getafe app		6-12	No Company
	ETSIINF UPM app		6-12	No Company
	TARIKÚ app		6-12	No Company
INDUSTRY	Argentarius	Sofya	6-12	Small

	app	Systems S.A		Company
	FLUX app	Kruger Corp.	6-12	Large Company
	Supermaxi app	Devsu SW	15	Small Company
	UNIDAL CRM app	Riverminds	3-6	Microenterprise
	ACMovil app	Arca Continental	15	Large Company

Q9. Level of rigorousness applying the methodology

All UA (4 industries, 4 academics) present a high level of rigor when applying the methodology for the development of mobile applications, presenting values 7-10.

Q10. Issues identified during the development process

All UA present some sort of difficulties during and with the development process. The issues reported are commonly about poorly raised or changed requirements in the process and lack of knowledge or tools for developing. In the Table 9, we show the challenges reported by the respondents.

TABLE 8. ISSUES IDENTIFIED WITH AND DURING THE DEVELOPMENT PROCESS: UNITS OF ANALYSIS

	Mobile Application		Issues
ACADEMY	SG Getafe app		Waste of time: wait for the "feedback" of interested people
	ETSIINF UPM app		There are issues with the functionality of the application: button errors, etc.
	TARIKÚ app		Lack of documentation lack of prioritization and lack of budgeting.
INDUSTRY	Argentarius app	Sofya Systems S.A	Lack of knowledge of the SDK for cross-platform applications. Web technologies such as JavaScript and Angular JS are inefficient in terms of resource consumption of the device.
	FLUX app	Kruger Corporation	User changes, support previous versions, and tests on different devices and versions of S.O.
	Supermaxi app	Devsu SW	The needs of the end user are ignored. The SW is difficult to maintain or modify. Developers do not write code that is easy to maintain, causing delays when adding new features.
	UNIDAL CRM app	Riverminds	Not having the necessary tools, it is an obstacle: to compile for IPHONE, an APPLE license is required
	ACMovil app	Arca Continental	A business mobile application requires data provision of legacy systems; the administrators of these systems did not always have the communication interfaces in time, which delayed the development of the mobile application.

V. DISCUSSION

In this section, we discuss the main findings of the study. We also highlight the limitations that may threaten the validity of the study and examine the implications for research in this field.

A. Findings

The main findings in the present research are:

- Almost all applications, 87.5%, were developed for smartphones. The vast majority, 62.5% of the UA were developed for the iOS and Android platforms, and with the same share are native applications. Native approaches were selected for reasons such as performance, use of sensors or projection of the mobile application.
- As for the industry, 40% of the UA are large companies and another 40% are small companies. Both show respondents with qualified experience and novices, being visible the lack of knowledge of development team members, as mentioned [6]: lack of informed and experienced resources to develop mobile apps. On the other hand, in a less favorable situation is the remaining 20% of the UA, the academy, which presents respondents with few or no experience.
- The majority of the applications (75%) invested 12 months or less for application development, making visible the short development time and planning required, as mentioned [6] [7]. This factor contributes several times to the selection of agile methodologies, as it happens with all the UA of the industry, which developed with agile methods, making use of SCRUM mostly, followed by XP and ADHOC, with equal percentages. As for the academy, the UA uses non-agile methodologies, but most are proposals (ADHOC). Using ADHOC, either with agile or non-agile guidelines, evidence the assertion: "developers rarely used formal development processes" [8], being a possible reason to create new proposals, the complexity for the development team to follow SW development processes that are not fully adapted to mobile application development projects [8].
- In the UA, several processes start with activities that involve requirements, then design and develop the application, and finally evaluate it. However, some activities that comprise the processes or methods identified are diverse or out of the ordinary, as is the case of an UA that establishes as an activity the development of C# language controls. On the other hand, only an academic UA uses specific requirements to cover the design standards to improve the UX. This leaves in evidence, the minimum or null adoption of standards that cover the variety of screen sizes, cameras, and the use of sensors: GPS, accelerometer, gyroscope, among others, which means that the functionalities of mobile devices are not properly exploited. The possible reason for wasting resources on mobile devices may be the lack of knowledge of the existence of these standards or avoid these guidelines in order to reduce the time for the development of applications [6]. In addition, it is worth mentioning that for a UA, certain web technologies such as JavaScript and Angular JS were inefficient in terms of resource consumption of the device.
- The vast UA majority of developers establishes activities relatives to usability with the goal to improve the user interaction and UX especially when size of screen is a great constraint. Nonetheless, they reports interface issues like button errors, which limit the functionality of the application. In addition, non-compliance with the time required to test different models of mobile devices. The possible reasons for having these drawbacks are to leave aside specific guidelines for applications on mobile

devices or the lack of knowledge of the developer, as mentioned in previous points.

- Certain challenges in mobile software processes or methodologies generally reflect delays in the development of the mobile application. The effort required at the beginning of the development process where the team spend a lot of time evaluating customer's requirements increase their workload with developing, integrating and testing the apps [6]. It is so, the UAs are adversely affected in activities that take a long time to wait, as are those related to requirements: waiting for approval or changes by users, not giving enough time for the correct lifting of requirements, or not taking into account the end user's needs on time. These issues combined with the limited time required for the development of mobile applications mean that the development team does not identify or avoid factors in the early stages of development, bringing these difficulties throughout the process.

B. Limitations

The main limitations of the study are related to the low experience of the respondent of the development team, the location of the vast majority of companies in the same geographic position and the possible ambiguity in the questions of the survey. Furthermore, a major limitation and threat to the study is that responses were received from people willing to be surveyed. There is a risk of receiving wrong or biased answers, as questions capture opinions, not facts. Community biases can be reflected in the results and having few UAs means that the survey sample does not represent the real world, and the result can be based on opinions and not necessarily proven facts.

C. Implications for Future Research

The findings mentioned above can be considered as a possible future research topic, and better, if data collection is improved through different survey versions and with geographically varied case studies.

The first ambitious implication is the formalization of the process of development of mobile applications, which can start with the establishment of rules or guidelines. These guidelines will allow leaning toward one process or another, taking into account different parameters such as the number of resources in development team, the time established for the development of the app, the level of knowledge of the development team members, among others.

A second implication is the study and proposal for the use of mobile device design standards. So that in the process that is carried out, these particularities that allow the improvement of the UX are taken into account, without leaving aside and taking advantage of the features and functionalities of mobile devices such as screen size, sensors, GPS, cameras, among others.

VI. Conclusions

In this paper, we have identified the scarce formal documentation about methodologies or processes of mobile application development applied by industry and academia, despite the thousands of mobile applications on the market. Given the greater interest for rapid application development, sharing their development experiences with the scientific community has become secondary. Thus, the main goal of this research was to contribute towards a greater understanding of mobile software development processes or methodologies applied by the industry and academia for the development of mobile applications. In this work, we have proposed a practical approach, based on case studies that form eight units of analysis (5 from industry and 3 from academy). During the analysis to identify and characterize the processes and methodologies in mobile application development, we have raised 10 research sub-questions to be answered in the context of each case study, leading us to the following main findings. Mobile application developers have few processes specifically defined for the mobile domain. However, among the identified processes Scrum becomes a reference, Scrum, since it is mostly used in the industry. The processes identified are based on agile and non-agile methods and methodologies that hardly integrate concrete activities of the mobile field, without being able to adequately exploit the functionalities and characteristics of mobile devices. In addition, it is verified that a latent drawback in the process of developing mobile apps is the lack of informed and experienced resources to develop mobile apps.

These results show the need to share and propose specific methods for the development of mobile applications that integrate features and restrictions of mobile devices, as well as usability techniques for improving the user experience when using a mobile app. Further research will tackle these needs and will include a broader practical experience, both in terms of units of analysis and research questions.

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