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A framework for the execution of automated regression testing

Ett ramverk för exekvering av automatiserade regressionstester

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Abstract:

Software testing is an important activity within the software development area, where regression testing is essential. Regression testing implies re-running test cases in order to ensure that changes made to the software do not introduce new errors and to guarantee that the system's functionalities have not been affected by those changes. To execute regression testing in manual mode involves valuable resources, specifically time and money. Therefore it is recommended to carry out this activity in an automated manner. A problem that faces the execution of automated regression testing is that testers are becoming specialized in specific test environments due to the existing diversity of tools used. Therefore testers would not be able improve test processes related to different environments. Thus, this paper focuses on identifying the current working manner within the domain of execution of automated regression testing and to improve it. Then, it has been necessary to conduct personal interviews (7) and a literature study in order to answer the study's questions. This work provides a general framework for testers to work more effectively with execution of automated regression testing regardless of the test environment. The framework includes 7 stages: (1) *Select test cases*, (2) *Execute/Run tests*, (3) *Monitoring/Analyzing results*, (4) *Write a report of the test results*, (5) *Archive the reports of the test results*, (6) *Estimate and assign the raised problems*, and (7) *Manage the test cycle*.

Keywords: *Automated regression testing, regression test, regression test execution*

Sammanfattning:

Inom programvaruutveckling är testning en viktig aktivitet där regressionstest är centralt. Regressionstestning innebär att exekvera om testfall för att säkerställa att de förändringarna som har gjorts i programmet inte har infört nya fel i systemet. Detta görs också med syfte till att kontrollera att systemets befintliga funktioner inte har påverkats negativt av dessa förändringar. Att genomföra regressionstester manuellt är resurskrävande i form av tid och pengar. Därför rekommenderas det att utföra denna aktivitet på ett automatiserat sätt. Ett problem som finns idag med exekvering av automatiserad regressionstest är att testare blir specialiserade på specifika testmiljöer på grund av det används många olika testmiljöer. Därför skulle de inte kunna stödja förbättringen av andra testares arbetsflöde. Således fokuserar denna studie på att beskriva de aktuella arbetssätt inom området exekvering av automatiserade regressionstester samt hur dessa kan utvecklas. Det har varit nödvändigt att genomföra personliga intervjuer samt litteraturstudie för att kunna besvara studiens forskningsfrågor. I detta arbete har det kommits fram till skapandet av en allmän ram för testare att arbeta mer effektivt med genomförandet av automatiserade regressionstestning oavsett testmiljön. Ramverket innehåller 7 faser: (1) Val av testfall, (2) Utföring/Exekvering av tester, (3) Kontroll/Analysera av resultat, (4) Skrivandet av rapport för testresultat, (5) Arkivering av testresultat rapporter, (6) Värdering och tilldelning av uppkommande problem samt (7) Hantering av testcykeln.

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1. Introduction

1.1 Background

Most professional companies prioritize and devote more time and money to testing, revising and retesting programs than writing them [1]. The costs associated with system failures caused by software bugs are high, e. g. annually the USA economy's estimated cost for bugs is \$59.5 billion [1, 4]. Other experts claim that more than 50% of the costs of software development are dedicated to testing [3, 33]. Therefore these organizations are willing to employ a lot resources to prevent system failures [1]. According to Smith, Tessler and Kramer [4], a third of USA's cost for bugs could be eliminated just through improved testing. Therefore, testing is widely adopted to ensure the quality of the software under development [6, 22].

Testing is included in the implementation phase of software development and involves several test activities such as test planning, test case design, test execution and analysis of test results [17, 33]. Testing can be executed by three methods: (1) manual, (2) automatic or (3) a combination of both [2]. Manual testing implies that a human goes through applications, trying various input combinations and compares the results to find defects [2, 5, 31]. However, automation testing is the process of using a computer program to execute system or user transactions against an IT system, without or with the minimal human participation [2].

Automated testing is important because it enables companies to save time and money providing time for the test team to focus on more challenging tasks [1, 2, 3, 6, 31]. It can contribute to improve efficiency of the testing process in order to identify areas of a program that are prone to failure [31]. Automation testing is usually suitable to regression testing [2, 3, 34], which implies re-running test cases in order to validate modified software and to ensure that new errors have not been introduced into previously tested software [33]. In addition, by using automated software testing, thousands of different and complex cases can easily be executed during every test run providing a large coverage that is applied in regression testing [2, 3, 34].

1.2 Automation and regression test

Automation testing is typically achieved by using automated test tools [2, 3]. This allows developers to identify problems quickly before the software is sent to quality assurance (QA) [2]. Automation testing is usually suitable to regression testing, performance testing, load testing, network testing and security testing [2, 3]. Introducing automation in regression testing projects benefits those involved in the assignment [5]. It contributes to improve communication between software developers by creating more commitment, which is an important aspect in working with automated regression testing [5]. In addition, regression testing is the most expensive test activity and may consume as much as 80% of the testing budget [6, 16]. According to Harrold [33], regression testing can involve as much as a third of the total costs of a software system's lifetime.

Regression testing is a type of test conducted in order to verify that changes to a system have not affected previously functioning software [17]. Also, it is done to verify that previously functioning software remains after a change [5, 16, 25]. It implies running the same tests over and over again and that executing using the same variables and conditions would not yield any new defects [32]. Thus, where possible, regression tests must be automated [32]. An advantage of automating the regression

tests is that more test cases can be added to the regression packs without much impact on the time [2]. But, on the other hand, working with automation regression testing can cause a loss of interest for the person executing the tests and then the possibility of potentially missing any new defects while executing the regression tests [32].

1.3 Research question and purpose

Previous research about working with automated regression testing and its execution mostly focused on particular tools and not on the overall picture [9]. This is a practical problem that according to Mika, Itkonen and Iivonen [9] does not help testers to improve their work because companies have particular organizational structures and as well different working methods. To create general theories is crucial because it permits the estimation of execution time required to achieve a specified reliability goal in advance of a project [8]. Then, more research is necessary in order to develop general models that increase the efficiency of execution of automated regression testing [7, 8].

Thus, the main research questions of this work are:

RQ1: What are the routines for working with execution of automated regression testing?

RQ2: How can we improve these routines?

The purpose of this study is to describe a general framework to work with execution of automated regression testing.

1.4 The structure of the thesis

This thesis is outlined as follows. Firstly the research method (section 2) is described in order to set the reader into the context of how this study has been made. A literature review is presented (section 3) to identify theoretical steps in working with the execution automated regression testing. In addition, an empirical study is also made (section 4) for mapping practical steps within the domain where all the information comes from the interviewees. Both identified steps are compared, analyzed and discussed in section 5, which is followed by section 6 where this papers conclusion and further work are included. To conclude this paper, the sources that support this dissertation are shown and an appendix is also included which shows the questions used during the personal interviews.

2. Related work

2.1 Regression testing

Regression testing is an important software maintenance activity to ensure the integrity of a software after modification [21]. According to Engström [16], *regression testing* is the verification that previously functioning software remains properly working after a change [16, 25]. It is also used in order to detect errors in changes in the software, which means that code quality further developed [5]. Regression testing is considered the final step in Test-Driven Development (TDD) because test cases are overtaken [5]. According to experts, the central role of regression testing in maintaining software quality [39].

A common approach used in regression testing is to reuse previously executed test cases where the main focus is to research how to maintain, select and prioritize among the existing test cases [17]. This type of testing is applied continuously at several levels, e. g. systems test [16]. Engström explains further [16] that regression testing strongly depends on the context in which it is applied. Design issues even affects regression testing since there is a strong relation between the efforts needed for regression testing and the software design [16]. Engström, Runeson, and Skoglund [25] claim that because regression testing involves verifying that the functionality of the software remains working as expected after implementing changes, it is important to know which technology is best suited for testing. It is crucial to take into account the context and compare it with the current development environment where regression testing technology should be implemented [7, 25].

2.2 Automated regression test

Automated testing is used according to Oezbek [5] as a term to distinguish it from manual testing, which means that human interaction is avoided during the test run to verify the software's response when given instructions. Issues related to test automation are usually: (1) assessment of cost/benefit of test automation and (2) environment for automated testing and the presentation of the results [16]. Also, test automation is beneficial to test reusability, repeatability, test coverage and effort saved in test executions [36].

Oezbek [5] claims that automated regression testing is a very well-known and established method to ensure quality in software development projects. Regression tests are used to determine whether existing product configurations and generated product outputs can be re-derived without unexpected effects [37]. In automated regression tests, the test cases are created by using an automated test case generator [20]. Even an execution report is generated in which the executed test cases are classified as successful or unsuccessful and then the next day developers examine the report and fix bugs [20].

2.3 Test execution

Test execution is described as the activity that occurs between developing test scripts and reporting and analyzing test results [24]. Many experts agree that test execution now becomes a critical activity in software development projects [23] and it is more complex than just clicking a button and monitoring machines [24]. This means that test execution activities are a little more than starting a test and monitoring it to ensure that the test will be running as expected.

According to Tian [18], there are three general steps in test execution which include:

- 1. Allocating test time and resources:** is mostly related to the test planning and preparation of activities, but the monitoring, adjustment and management of these resources need to be carried out during test execution.
- 2. Running tests and collecting execution information and measurements:** it is relatively simple with well-prepared test cases or already sensitized test cases.
- 3. Checking testing results and identifying systems failures:** here the most important part is to handle failed test runs where the key is to ensure that this failure will not block the execution of other test cases.

Black [19], explains that the best outlines to a good test execution process include seven important stages:

- (1) Select a subset** of test suites from the test cohort which means all the test suites that apply to the current test phase.
- (2) Assign the test cases** in each test suite to testers for execution.
- (3) Execute test**, report bugs, and capture test status continuously.
- (4) Resolve blocking** issues as they arise.
- (5) Report status**, adjust assignments, and reconsider plans and priorities daily.
- (6) Manage the test cycle**, (test cycle: selection of a test suite, often a subset run against a particular test release) eliminating unrealizable tests in reverse-priority, lowest first and highest last.
- (7) Report test cycle findings** and status.

In addition, Meier, Farre, Bansode, Barber and Rea [24], states that performance test execution involves activities such as (1)Validate the test environment, (2)Validate tests, (3) Run tests, (4)Baseline and benchmark, and (5) Archive tests. Those stages are explained in table 1.

Table 1. “Test execution general stages”, [24].

| Stages | Explanation |
|---|---|
| 1. Validate the test environment | Before running your tests: -Validate the test environment so that it matches the configuration of the test. -If the test environment differs a little from the environment where the tests were designed, there is a high probability that tests might not work at all or that they will work but will provide misleading data. |
| 2. Validate tests | -To understand the data collected from a test run, the simulation must accurately reflect the test design. - If the simulation does not reflect the test design, the results are inclined to misinterpretation. |
| 3. Run tests | The process and flow of running tests are extremely dependent on the tools, environment, and project context. |
| 4. Baseline and benchmark | - <i>Baseline</i> is the process of running a set of tests to capture performance metric data to evaluate the effectiveness of subsequent performance-improving changes to the system or application. - <i>Benchmarking</i> is the process of comparing the system performance against an industry standard that is certified by other organization. It involves running a set of tests that comply with the specifications of an industry benchmark to capture the performance metrics for your application necessary to determine its benchmark score. |
| 5. Archive tests | -It is up to the team to decide what method is best for them. In most cases archiving tests, test data, and test results saves much more time than it takes over the course of a performance-testing project. -Example: Some teams prefer to check test scripts, results, and reports into the same version-control system as the build of the application to which they apply while other teams simply save copies into dated folders on a periodic basis. |

The crucial part of the overall test execution is the smooth transition from one test run to another, which also requires the allocation of all the resources to ensure that individual test runs can be started, executed, and finished, and related problems can be handled seamlessly [18]. To validate the test environment to ensure that the environment truly represents the production environment is even central [24]. In conjunction, testers also need to interpret the test case results correctly to ensure the execution processes quality and therefore test case execution also involves looking for mismatches between expected and observed results [19]. In addition, accidental overlapping of testing should as well be avoided [19].

2.4 Identified steps based on theory

To design a model it is central to think about three aspects: (1) boundary, which means to create a moderate model regarding size and complexity, (2) input and output, which means first to choose the most sensitive data relative to the phenomena you want to model, and (3) level of abstraction, meaning how detailed the model will be and if it is too detailed the model may become too complex [14]. Also, it is important to explain that in earlier research papers, similar frameworks have not been found as the one shown in figure 1. Other frameworks that have been mapped during this study are related to, e. g. implementation of automation, techniques to select tests cases and different algorithms to reduce test case suite size, which do not match the specific domain of this investigation, i.e. the execution of automated regression testing. Thus, the author of this thesis has created a model (see figure 1)

to summarize the relevant theories chosen to the investigation in order to illustrate how the theories are linked to the research's problem.

The following model is designed in this subsequence: on the left, three boxes encapsulate general categories such as *Test Execution*, *Regression Test* and *Automated Regression Test*, where each category corresponds to the three previous sections of this chapter. The arrows on the top of the boxes indicate that they are the direct input to the final set of steps shown on the right side of the model. Then, *Identified Steps* are the output of the model, where six stages were selected based on the model's input. Many of those stages overlap each other and therefore only six of them are included in the model outcome.

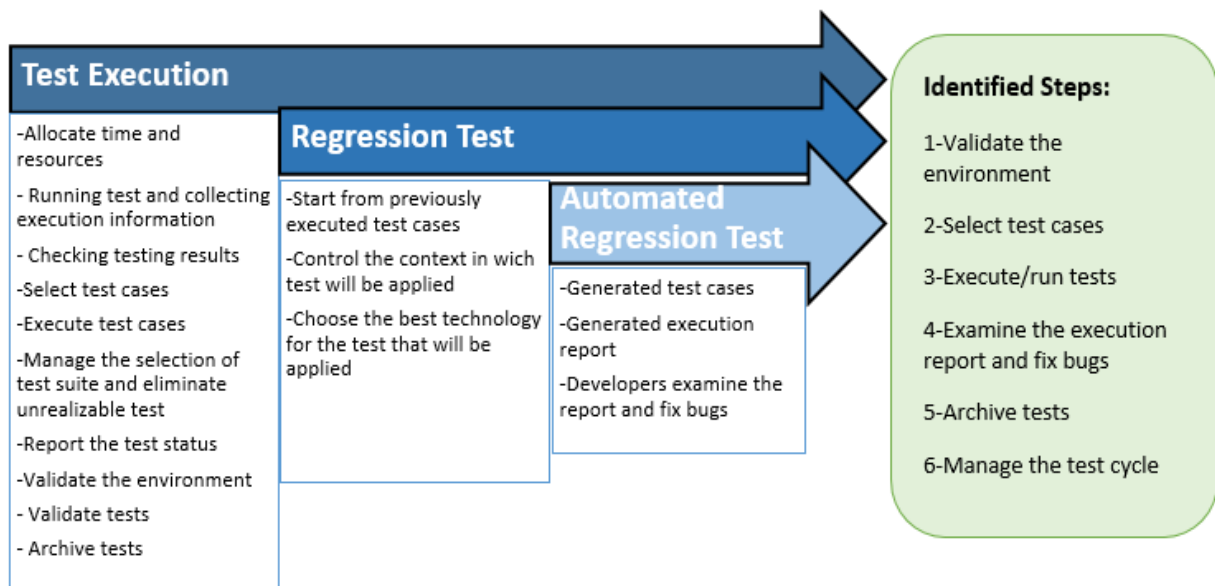


Figure 1. “Steps identified from the literature review” model.

Steps identified from the literature review:

- 1- *Validate the environment*: refers to checking if the test environment has the correct configuration in relation to the test that will be run [19].
- 2- *Select test cases*: refers to the selection of test cases that apply to the current test phase [19].
- 3- *Execute/run tests*: this process depends on the specific tools that are used during the test where the most important is to ensure that failures do not block the execution of other test cases [18, 24].
- 4- *Examine the execution report and fix bugs*: when the results of the test cases run come out, it needs to be analyzed to determine the error's source and then solve it [18, 19, 24].
- 5- *Archive tests*: may be conducted in order to have a basis to analyze the failure's sources and how often they occur [19, 24].
- 6- *Manage the test cycle*: test cycle is the selection of a test suite, where often a subset run against a particular test release. To manage this, it is important to eliminate unrealizable tests in reverse-priority, lowest first and highest last [18, 19].

3. Research method

3.1 Research design

3.1.1 The role of theory related to data

The relationship between theory and research can be understood in two different ways: (1) "theory" comes first in the research which means a deductive approach, and (2) "empirical context" comes first to derive the "theory" which means that the researcher has an inductive approach [11, 12, 13]. This study is based on a theoretical frame of references to create a framework about how to work with execution of regression test. This framework will be validated through empirical data and therefore a more deductive approach is adopted. According to Jacobsen [12], a deductive approach means that the researcher begins with some assumption and then collects empirical data to see if the assumptions hold, or if they need to be changed.

3.1.2 Type of data

According to Jacobsen [12] data can be divided into two main groups: (1) qualitative or quantitative data and (2) primary or secondary data. All type of data talk about the reality, but qualitative data refers to its measurement by words while quantitative data focus on numbers [11, 12, 13]. In this case, qualitative has been used in order to collect as much information as possible about how testers perceive the phenomenon to work with automated regression testing.

Information that is collected directly from people or groups of people's experiences is considered primary data, while secondary data is information that has been collected for other purposes and not directly from the source by the researcher [11, 12, 13]. For this paper, it is vital to choose both type of data to be able to answer the study's purpose. Therefore, tester/experts experiences and stories in working with automation regression test have been collected directly from their own perspective, which corresponds to the study's primary data. The secondary data is collected in the form of a literature review from various libraries to obtain relevant information. Jacobsen [12] states that the benefits of different types of data provide advantages to the research because they can be used as independent sources to verify the results of the analysis.

3.1.3 Qualitative approach

According to Jacobsen [12], qualitative data that has been collected through qualitative methods leads to a qualitative approach in the work. Furthermore, the qualitative approach works best when the researcher is interested in what the individual says, and it is more flexible and has higher internal validity than the quantitative approach [12]. In this case, two techniques have been used to gather information, personal interviews and a literature review, which according to experts [11, 12, 13, 14] are methods for collection of qualitative data. Thereby, those gathered facts have been analyzed using descriptions (text) for both research questions. It leads to a qualitative approach which is adopted in this study that is summarized in figure 2.

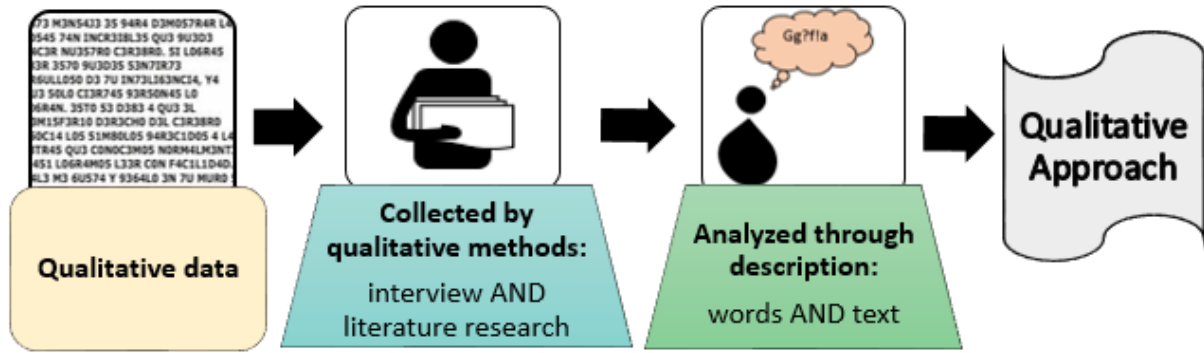


Figure 2. "An overview of the research approach"

A quantitative approach to this study has been discarded based on two central criteria. First, the author of this work perceives the reality as a construction where each individual has a unique manner to interpret a certain phenomenon. Therefore, people's experiences and their understanding about working with automation regression testing is the interest of the author. According to Bryman and Bell [11], and Jacobsen [12], it is suitable to assume a qualitative approach when the researcher is interested in participants' perceptions and meanings. Also, unexpected data has arisen during the interviews when respondents explain their work practices. This is supported by the qualitative technique which conforms to Jacobsen's view that this method [12] is more open to new and unexpected information method than a quantitative method [12, 15].

The second reason for not choosing a quantitative approach is because the research goal is to describe a general framework for working with execution of automated regression test. This implies clarifications, explanations and reasons, which would be difficult to capture by e. g. using questionnaires with closed questions and given response options. A quantitative method enforced the response into categories of answer such as "yes", "no", "totally agree" or similar, which are signals of less openness [12, 28]. According to Seaman [28], the principal advantage of using qualitative methods is that researcher is forced to explore the complexity of the problem rather than adopting abstract assumptions.

3.1.4 Study design

Bryman and Bell [11] describes "*study design*" as a framework for collecting and analyzing data. There are different strategies for designing a research study including the *case study*. It means that the researcher focuses on a special phenomenon or a simple case that can be defined in both space and time [11, 12, 13, 14]. According to Jacobsen [12], a case study is appropriate when the researcher wants to go in-depth in particular cases and for theory development. In this research paper, a case study has been chosen as the most suitable design form where the focus is on the phenomena of working with execution of automated regression testing. This design is also based on the report's main purpose which is to describe a general framework to work with execution of automated regression test.

The study design is summarized in figure 3, where the inputs of the model are both primary data and secondary data. Then each input has been analyzed separately, in order to identify current steps at working within the domain, i.e. detecting stages from the practice and from theories. Those parts of the result have been compared and analyzed to create a new model with complementary parts coming from both

inputs. This has been done, in part, due to the reason that the identified steps have been missing/not suitable from one or another perspective. Finally, the output of the figure corresponds to the result of the research, i.e. the newly created proposed framework.

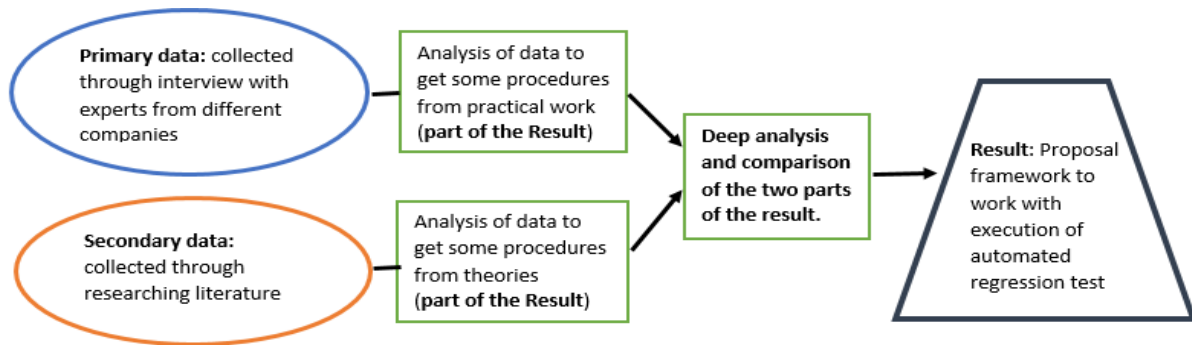


Figure 3. “Summary of the study design”

3.2 Interview study

3.2.1 Personal interviews

A personal interview is defined by Jacobsen [12] as a conversation between the interviewer and the interviewee, where the information that is gathered comes as words, sentences and narratives. It can be made face to face, via telephone and by video [12]. The interview is the most common technique in qualitative research when the aim is to acquire information about someone’s experiences [1, 27, 28, 29]. Then, based on this paper’s goal, the interview is defined as the most suitable method to obtain primary (empirical) data. To directly ask people how they perceive a phenomena is considered the most useful form to understand how their reality looks like [12, 13].

An interview can be entirely open, completely structured or semi-structured [11, 12, 13, 14]. When the conversation is not controlled by any interview guide, the interview is completely open [11, 12, 13, 14]. If instead the scientists determine the issues in advance and in static order then the interview is entirely structured [11, 12, 13, 14]. Thus, a semi-structured interview can be with an interview guide that has some themes and some questions in sequence [11, 12, 13, 14]. In this case an in-depth and semi-structured interview has been performed, which is also called a focused interview [29]. In this case, the themes for the interviews were inserted into open and also closed questions in order to get deep and nuanced perceptions of how they work with the execution of automated regression testing.

In addition, mobile recording has been used during the interviews to minimize the risks that relevant information is lost or misinterpreted. However, many interviewees can be adversely affected by being recorded [12, 13, 14]. By explaining to the interviewees the research goals, why it is necessary to record the conversation and by guaranteeing their anonymity, that effect has been counteracted. According to Jacobsen [12] a suitable time for an interview is between one, and one and a half to two hours. The interview length has been estimated between about forty five minutes and an hour. This time has been decided in order to open the possibility of getting responses from potential respondents to be interviewed as soon as possible.

3.2.2 Selecting interviewees

To select the interviewees, people from four different companies have been contacted in order to get relevant and useful information about the workers experience using automation to execute regression testing. The reason for this is that the resulting model is a general framework to support tester's labor within automation regression testing, regardless of the place of work. Then, it is central for this investigation to collect practices from a variety of working environments. This strategy is supported by a method to select respondents known as "wide and variation criteria", which implies that people can be chosen because they are able to provide special or interesting information to the researcher [12].

Seven experts in the field of automation regression testing or with software engineering as their educational background were selected and interviewed. According to Lethbridge, Sim and Singer [30] people tend to be comfortable with the opportunity to answer questions about their work. The contact with the participants was possible through a personal contact and other acquaintances. These experts were willing to provide information to the research and therefore selected. This type of criteria for selecting respondent is called "the information criteria" [11, 12] which means that the researcher can select respondents on the consideration that they can provide abundant and good information. Even if there are several different criteria for the selection of respondents in qualitative methods, the choice is directed by the study's intention [12].

3.2.3 Designing interview questions

Bryman and Bell [11] states that an interview guide is a list of questions reflecting different topics in a more or less unstructured interview. According to Dennis, Wixon and Roth [1] there are three types of interview questions. The first one is named as *close-ended* questions which are used when the researcher is looking for specific information and requires specifics answers [1]. *Open-ended* questions are the second type of interview questions. They are designed to gather rich information and give the interviewee more control over the information that is shared during the interview [1]. *Probing questions* are often used often when the interviewer is unclear about the interviewee's answer [1]. It is important that the timing of the interview questions allows the researcher to obtain information about the interviewee's experiences and to be flexible with the questions [11, 12].

In this case, an interview guide with ten questions in sequence and theme has been constructed. Designed interview questions and themes facilitate people to answer them [1, 11]. Two questions are classified as probing in order to allow the interviewer to encourage the interviewee to expand on information from the previous response. In addition, four open-ended requests appear in the interview guide in order to give space to the interviewees to express more freely in relation to the question's theme, which also supported by experts [1, 11, 12]. Finally, four close-ended inquiries are used with the purpose of control the interview and gather the specific information. Researchers explain that by using close-ended questions in the interview it is viable to get direct answers [1, 11, 12, 13]. (see table 2)

Table 2. “Classification of the interview questions”

| Interview questions | Classification |
|---|----------------|
| 1. Can you describe your work? Example: the input and output, the processes and tools used. | Probing |
| 2. How would you personally define automated regression testing? | Probing |
| 3. For how long have you been working with automated regression testing? | Close-ended |
| 4. Do you have some specific activities or framework you follow to work with execution of automated regression testing? a) If not, please could you explain how do you work with automated regression testing and its execution? | Open-ended |
| 5. What tools do you use for the automated regression testing? | Close-ended |
| 6. What advantages are there with the current activities/framework for execution of automated regression testing? | Close-ended |
| 7. What disadvantages are there with the current activities/framework for execution of automated regression testing? | Close-ended |
| 8. How do you think these activities/framework can be improved for the execution of automated regression testing? | Open-ended |
| 9. Are there any aspect/steps that you realize are "a must" when working with the execution of automated regression testing? | Open-ended |
| 10. Is there anything you would like to add what we have said? | Open-ended |

Interview questions and topics are based on the study’s theoretical framework about how to work with execution of automated regression testing. Questions are organized into a logical sequence starting with more broad question such as *Can you describe your work?*, and gradually goes toward more specific issues, for example *What tools do you use for the automated regression testing?* (see above 2). This approach is called “top-down interview” and enable the interviewer to understand the issues before continuing to the more specific details [1].

3.2.4 Preparing for the interview

To prepare an interview, it is crucial that the interviewer has a general interview plan with the discussion questions in an appropriate order [1]. At the same time, the questions should flow smoothly between the related topics [1]. In this case, the questions were designed to provide a logical and interrelated flow of information. First, questions about their work with execution of automated regression testing appear (see Appendix A1). In the middle of the interview, the interviewees describe the advantages and disadvantages of the procedure that they use at work. Finally, they are asked if they would like to add something else to the conversation. The questions’ structure allows combining the possibility of getting specific answers by

having closed questions, but also letting the interviewees to respond in an unexpected manner. The reason of that is to contribute getting more nuanced information. According to Dennis, Wixon and Roth [1], the researcher should be careful by selecting open questions only, therefore there could be a risk to fail to gather important information in the interview. It implies that the researcher would need to interview the same person again and that would be an ineffective use of time and resources [1].

In addition, an email was sent to the participants two days before the interview. This was done in order to describe the purposed of the study and also the interview questions were attached. It is supported by Dennis, Wixon and Roth [1] where they argue that those aspects should be sent to the respondents far enough in advance in order for them to have time to prepare for the event [1].

3.2.5 Conducting the interview

The seven interviews have been conducted based on the same interview guide and tactic for each interview. The author of this thesis carried out the interviews in a face to face manner in order to interact more with the interviewee. According to Jacobsen [12] it is an effective strategy to interview, therefore the researcher can also interpret the interviewee's body language. It is also an advantage to use this type of interview because the interviewer has the opportunity to clarify questions to the participant and at the same time, interviewees can give unexpected responses [30]. Thereby the researcher can be able, for example, to observe how comfortable the respondent actually feels during the discussion.

When meeting the respondent, the first thing was to bring a quick overview of why this research is being conducted in order to create a certain degree of trust. Experts explain that it is necessary to establish a trust relationship between interviewee and interviewer [11, 12, 13]. Then, a short description about the interviewer was also made in order to explain who is she and her background. According to Jacobsen [12] the investigator must be very careful and thereby clear when introducing themselves to unknown persons to not affect the interviewee's trust. In this context some aspects should be said, such as to introducing yourself by name and background, to communicate clearly the purpose of the interviews and to explain how the upcoming interview information should be processed to ensure the privacy, integrity and personal protection of the respondents [1, 11, 13, 14].

3.2.6 Post-interview

The data collected through interviews was transcribed directly. In general, researchers should write out and summarize material about the interviews within forty eight hours after the interview since waiting too long time could risk that the information can become forgotten [1, 14]. At the same time when the interviews were recorded, notes were written in order to reduce the threat of losing information or misunderstanding it. This technique is supported by Höst, Regnell and Runeson [14] when they explain that the investigator can take notes during the interview as a complement to the recording. Furthermore, this is an appropriate strategy to get an idea of what is important during the interview [14].

3.3 Literature review

3.3.1 Searching process

Many researchers agree that it is important to have multiple sources of evidence when writing assignments in general because every potential sources provide a different perspective and at the same time certain limitation [13]. To find relevant information to support this study it has been necessary to search data both off line and on line. Literature from both physical books to support the analysis and digital sources to choice scientific articles have been made.

The digital search was made using the web portal ACM and where only journal articles in computer science topic are published. Academic Search elite, Summon and Google Scholar were also used to map vital sources. IEEE was explored to collect journals but some papers were not free of charge. Then, as an alternative, the same search term was introduced at Malmö University digital library with successful results in most of cases.

According to Conway [10] it is convenient to search information by using keywords because they can be used as a substitute of subjects, titles or author when you have incomplete information. In this paper many keywords have been used to find out relevant data. The following keywords were typed in digital libraries and search engines:

- Activities of test execution in software testing
- Automated Regression Testing
- Automated Testing
- Execution of automated regression test
- Framework for Automated Regression Test
- Regression Testing
- Test execution
- Test levels
- Test performance

3.3.2 Obtaining and assessing

When collecting the literature necessary to support this study essential criteria were considered in order to ensure the quality of the data. For example, all searches made online in databases were “peer reviewed”. When typing the term “test execution”, it came up 235 publications were found but when selecting only peer reviewed 226 were shown. Another criteria to discard material was by controlling that the journals abstract explicitly was related to the theme of this paper. Also, it was important to select material that was in the specific domain of this study which is execution of automated regression testing, and not from testing in general.

3.3.3 Reading and critically evaluating

The articles were read in the follow sequence: first the author of this thesis read through the abstract in order to select relevant information to this study. If it was something interesting related to the research, then the introduction and conclusion were also read. Sometimes after reading the conclusions, it was evaluated that the material was not related to this study. In many cases, the information was relevant and then, titles of the sections, tables, graphs and explanations were also explored in order to get a better understanding of the theme.

3.3.4 Recording

Articles, books and other materials were examined and a summary of its contents was written in order to identify important details from the articles' findings. Also, annotations about the source of the information were made. For example, aspects to write about were: the author of the articles, when the material was written and which references were used by the researcher.

3.3.5 Writing a critical review

Even if many articles content could be used to support this study, sometimes it was difficult to do it due to not correctly understanding some concepts and explanations. It was necessary to find additional journals that by a more basic form could explain the themes. For example, specific and complex mathematical algorithms to reduce test suites size in regression test, could not be understood the first time.

3.4 Approach methods for data analysis

The amount of collected information was reduced in order to provide the researcher an overview of the data. Jacobsen [12] explains that description, categorization and combination of data are central stages in the analysis process of qualitative data. Categories should be relevant to the collected data and to the existing theoretical/empirical data on the subject, and has meaning for other relevant actors like readers and investigators [11, 12]. In this case, information from the interviews has been categorized by directly relating to the answer with specific keywords. Eventually they were categorized in subcategories to look for an established relationship between that information and each subcategory.

The data analysis is even founded on the theoretical framework about how to work with execution of automated regression testing, created and shown in the subsection 4.5. The collected data was first written down and then commented upon, which gave an overview of the possible categories and pointed specific themes. After that stage, information was encoded to the main categories such as *test execution*, *regression test* and *automated regression test*.

3.5 Validity and reliability

The concept of *Validity* refers to a measuring instrument's ability to measure what it intends to measure while *Reliability* means that a measuring instrument will provide reliable and stable results [13]. To investigate how reliable an investigations result could be, the researchers should analyze three important aspects: (1) if the selected method actually measures what they claim to measure (internal validity), (2) the degree to which the findings of a study can be generalized (external validity) [27], and (3) if it is reliable (we can trust them) [11, 12, 13]. Based on these criteria, the scientist can evaluate how good the research findings really are [12].

In this case, *personal interview* have been selected as a method to collect data in order to obtain information directly from people's experiences in working with execution of automated regression testing. Furthermore, the empirical data related to, for example, what is automation regression testing, was collected from experts that work or have been working in the investigated area. This is evidence to that correct persons have been selected to obtain the needed information. According to Eriksson and Wiedersheim-Paul [13], to collect data from the correct source provides a high external validity.

Regarding the secondary data, the biggest threat to sources validity has been the possibility to have lost relevant material because of the terms used when searching in databases. For example, terms such as automated test/automation or regression testing/testing may return different results. Eriksson and Wiedersheim-Paul [13] states that an analysis of source credibility counteract risks of less validity therefore the author shows his awareness of the problem. In addition, different sources have been used through the whole report in order to take into account many experts criteria in the field, which according to [13] is essential to enhance the report's validity.

3.6 Limitations of the study

Several limitations may be identified in this thesis. First, the results of this study only affect the execution of automated regression testing topic within the software development industry. According to Jacobsen (2002) the researcher needs to take into account the degree to which the findings of the research can be generalized. Second, the research design of this study is a case study in order to provide specific and nuanced information to the research. Nevertheless, according to Jacobsen (2002) a case study provides more depth and detailed information but less generalization. Last and not least, the fact that the population of the study is made of seven interviewees could influence negatively the generalization of the results of this this thesis. The number of interviewees could be increased but due to lack of resources such as time, and access to the suitable interviewees, this has not been possible to accomplish it. Therefore, the author of this paper realized that the research biggest limitation is to have a low external validity.

3.7 Research ethics

Research ethics means to reflect over the dilemmas that the researcher faces in balancing their own desire of getting as complete and reliable information as possible and the interviewee's demands for privacy, integrity and personal protection [13]. There are basics principles in research ethics such as the interviewees in a survey to do it voluntarily and by his/her own desire [14]. According to Jacobsen [12] requirements of *informed consent* about privacy, anonymity and being a confidentiality becomes stronger if the investigation involves a greater threat to the surveyed. In this case, the interview questions were not addressed to aspects that the interviewee could experience as private, for example *how much salary he/she earn per month*. This strategy fits the code about to avoid sensitive questions conforming to the interviewee's right to privacy.

The name of the four companies where the interviewees work and the name of the interviewees are not shown in this report therefore the anonymity has been guaranteed. Anonymity means that the interviewee is not identified [13]. The conversation's recording is also anonymous, which means that all data providers cannot be identified through the dialog. That information is used only for the purposes of this study. Thus, the author of this paper has taken into account fundamental ethical aspects of the research in order to avoid unnecessary problems. In software engineering research, ethical standard must be maintained for long term trust to be upheld [27].

4. Result of the empirical study

4.1 Interviewees background

The experiences of seven interviews about how to work with execution of automated regression testing have been described through this entire chapter. All interviewees are working in companies with at least 150 employees. One of these companies is world leader in communications technology providing equipment, software and services (**a** in table 3). Another enterprise (**c** in table 3) supplies professionals with focus on testing and is Sweden's largest independent quality assurance (QA) corporation for IT systems. The other two companies develop software and hardware where testing is a key activity, e. g. operative systems (**b** in table 3), security solutions in network video (**d** in table 3) and equipment to build networks for mobile communications are companies' core activities.(see table 3)

Table 3. "Interviewees background"

| Respondent (R) | Works position | Experience (years) | Company | Employees |
|-----------------------|-----------------------|---------------------------|---|------------------|
| R1 | Tester | 15 | a. large company, telecommunications industry | 17 000 |
| R2 | Technical Manager | 8 | a. large company, telecommunications industry | 17 000 |
| R3 | Software Engineering | 3 | a. large company, telecommunications industry | 17 000 |
| R4 | Software Engineering | 5 | b. large company in delivering operative systems | 300 |
| R5 | Tester | 5 | c. medium-sized company specialized in testing | 150 |
| R6 | Tester Leader | 19 | d. large company specialize in security camera systems | 913 |
| R7 | Engineering/Manager | 6 | a. large company, telecommunications industry | 17 000 |

As shown in table 3, the work experience of the interviewees ranges from 3 to 19 years. The seven interviewees are involved in testing tasks and have experiences in regression testing, most of them within the telecommunication industry. One of the interviewees, R2, works as a manager for a regression test department in a large company. Another interviewee, R7, is responsible for regression testing planning, e. g. he is involved in the analysis and selection of the group of test to be applied to his company product. A third interviewee, R1, has previous experience in test tool development used within the own company. Some of them have been involved in the evaluation/examination of the failed test results. Four interviewees, R3-R6, are directly working with software testing and with device testing or hardware testing.

Most of them have had previous experience in software development and all of the engineers have as daily tasks testing, integration and verification.

4.2 About automation regression testing

According to R3 and R4, in telecommunications, software development evolves rapidly where newer and tougher requirements to meet the progressively changing networks arise continuously. However, legacy protocols remain since it is not possible to replace the existing ones. Therefore, software projects have to implement plenty of new features but still make sure all the old ones work, hence making regression testing a crucial part of software development, explains R4.

At the same time R5 explains that development processes need to be faster than ever in order to meet windows of business opportunities. It can often be found that a number of companies making competing software solutions in which the first one to reach the market counts with a tremendous advantage. Thus, project deadlines become more and more challenging, making automated testing the only alternative to produce software that meets the quality requirements in the given time, explains R5. The same interviewee continues to explain that automation is the only approach feasible for regression testing due to an industry that evolves fast yet requires legacy support within a competitive context in which software pace needs to be as close as possible to its peak.

The interviewees refers to automation testing as follow:

“Automated regression testing is for me the natural evolution of regression testing”, says R5.

“You cannot live without automation”, says R1.

Automation regression testing is perceived by the interviewees as a manner to continuously test all changes made during the development process. They clarify that testers select a group of tests cases to ensure that the changes have not affected the already existing functionality contained in the system or device. According to R4, it allows testers to continuously run large volumes of test cases to find as many errors as possible in a short period of time, thus accelerating the process to a final and robust product. For example, when testing a website, all the links need to be tested to ensure that they are redirecting to the correct sites. If there are many links, then this repetitive action of testing can be automated. Automated regression testing is used for reoccurring validation, argues R2. Furthermore, this interviewee claims that if it includes the selection a test before every new deployment of a software, then it is suited to use automated testing.

According to R7, automation testing is a system that:

- Executes a set of predefined test or set of tests.
- Provides the user with a predefined pass/fail criteria, as well as detailed information of the results for each test executed.
- Identifies faults or errors in the test environment, not related to the test or the item being tested.
- Is triggered and completed without or with minimum human intervention.
- Provides a known result for a known input every time, for example the results should be consistently repeatable according to certain required specification.

- Returns to a known state if the test environment fails, and re-starts the test.
- May include a queue system to increase efficiency.

The interviewees share the view that having automation method to work with regression testing is really important because it permits testers to run thousands of tests, which facilitates this labor. Therefore, they consider that much time and money is saved by working with automation regression testing.

4.3 Activities performed at working with execution of automation regression testing

According to interviewee R4, the used technique in the company, to working with execution of automated regression test is to run an entire collection of regression tests overnight. Furthermore, this interviewee explains that the collection of regression tests used come from 3 different origins: (1) they are either implemented by the company's test engineers, (2) they are inherited from software communities that test similar software functionality, or (3) they arise according to test standards such as Linux Test Project (LTP), Linux Standard Base (LSB) or Carrier Grade Linux (CGL). Then, results are monitored by the test department and introduced into the company's bug tracking system (JIRA). Since the corporation works according to the agile software methodology of Scrum, outstanding problems are brought into planning meetings, which take place regularly, so that they are estimated and assigned to engineers or departments, claims R4.

The interviewees in general agree that the first step is to decide which group of test cases that will be used for regression testing. They explain that the criteria for the selection varies from company to company but in general the focus is on testing basic functions according to the requirements specifications. Then a short analysis is done to decide how often the test suite (group of test cases selected) will be run, every hour, daily or every week. According to interviewee R1, the test runs at least 2 times and by using automation the tests run during the night and the results are available when experts come to work the next day. Then, the tests that have failed are analyzed in order to investigate the error's source, which may be the software/device under test or the test environment itself. Regression runs again, first based on those test cases that failed more than one time. The interviewees R1-R4 explain that if the failure persists and the tester is not able to find the reason, a routine is to create a so called "Ticket". They describe that this is an internal report with the failure descriptions of the test and that will be assigned to the developers for more investigation and correction.

According to the interviewees, the name of the test result's report (ticket) varies depending of the tools used at the company, for example "Problem report", "Error report" or "Incident". The results not only consist of verdict Pass or Fail, but also it made it possible for the experts to follow the traced execution and try to find the reason of the failure, in case the test fails. All results with fail and pass verdict are stored in a database. Interviewees agree that by doing this ticket/report the managers or test leaders can create statistics that help them to take decisions about how to proceed, for example if it is worth to continue using the same environment or not. (see table 4)

“The analysis of results is also a part of the execution of the test because if you are not able to see how the tests have gone, then it is really a waste of time”, says R3.

The interviewees claim that, in many cases, the test environment they use consists of equipment developed by external companies. These equipment or simulators contain its own tools for the preparation and execution of the test cases. The test tools used by the interviewees vary depending of the company they are working for. Open Source, company specific or test equipment specific tools are most commonly used.

Table 4. “Summarizing stages at working with execution of automated regression testing”.

| Stages | Explanation | Respondent (R) |
|--|--|----------------|
| 1. Select test cases | Predefined test cases. | R1-R7 |
| 2. Prepare the environment | -It can be made by the testers themselves, but other team at the company or suppliers do it. Preparation often includes “self-test/sanity check”* of test environment which is commonly used when test environment consists of complex instruments. | R1, R7 |
| 3. Tests cases runs | - It should be done preferably during a time when the test environment is used the least, and/or when there inflow of code to be integrated is the lowest, e.g. in a multinational company with teams spread all around the world, code is being integrated 24 hours. -Preferably during the night. | R1-R7 |
| 4. Monitoring/Analyzing the results | -Identify the error’s source: is it an issues from the tested software or is it the test environment? - Main problems are estimated and assigned to engineers or departments for investigation and correction. | R1-R7 |
| 5. Pick up the correspondent product release | -To rerun test cases the same day. | R3 |
| 6. Storage the results | -To get statistics: the error’s cause and frequency. - To further analysis: if it is worth to continue using the same test environment or not. | R1, R4-R7 |

*Self-test/ Sanity check: is an internal test to check basic functions of the test environment.

4.4 Advantages and disadvantages with the actual work flow

4.4.1 Advantages

The interviewees experience that big advantages are that the process “testing-execution-testing” takes less time. They explain that if repetitive and monotone actions are automated, then this can replace manual work. According to R2, usually the testers get result reports that are automatically generated after the execution,

instead of manually summarizing them. If more information is gathered automatically (without manual time consuming investigations) about the failed results then the problems can be analyzed faster. Also if the basic functionalities are tested by automated testing then there could be more time to run exploratory testing and test "outside the box" and in that way find new defects, explains R7.

"Reduction of boring repetitive tasks = happier staff + time spent on important items. Cheaper production/ increased efficiency. Human error factor is highly reduced, given that the system is stable.", says R7.

Some interviewees state that the main advantage is also that the professionals already have the results in the morning. The big testing work load is done during the night, which means that the demand of testing could be less during the working hours, thus avoiding the situation of waiting to have test environments available. Furthermore R3 describes that in the best case, the developers can correct the errors the same day and test again during the night. This is a very effective way of working and saving time and money for the company. Having all the results in the morning can provide the testers with an overall idea of the status of the Software/Device under test. According to R2, this information can be used as well to communicate with the customers and give them a short report about their product's status, which facilitates the work.

4.4.2 Disadvantages

The interviewees have identified weaknesses of working with executing of regression test in an automated manner. First, a lot of resources must be employed to take care of the test system/environment, to make it stable and to have it up to date, explains R1. Some interviewees using instruments as their test environment, explain that it is important to have people just to take care of the test instruments in the test laboratories. But, this is a conscious and necessary strategy because despite the cost, it will be more expensive to have an unstable test environment, claim the interviewees. Another disadvantage is that sometimes it is difficult to find a test environment that suits all companies testing needs.

According to R7, another problem the companies face is that it is very difficult to cover all possible scenarios, without increasing complexity and time. Upgrading and updating the test system requires team synchronization and may add project delays or risks of introducing errors. This interviewee continues to explain that the amount of storage needed can increase dramatically and the stability needs to be stronger. There are many problems that need to be fixed all the time and many things that can go wrong during the test with automated tools, argues R4. For example, testing can be complex and much equipment is involved which implies that if one of those equipment fail, then the execution of the test goes wrong, describes R1. In addition, if a requirement is misunderstood or the test cases are prepared wrong, this can have larger impact than when manual testing is applied.

Execution of automated regression testing as well requires a good risk analysis in order to choose a correct set of test cases, claims R7. If a proper risk analysis is not made there can be a risk that unnecessary function areas are tested and the necessary are not. According to this interviewee, if a software has a lot of reoccurring defects in one functional area, then this is a risk area. If this area is missed and not covered by the regression test cases then, the test exception will have the wrong purpose and miss the areas needed to be tested. This is also applicable for manual

testing but with automated regression testing a larger effort is required to prepare and set up the test cases, says R6.

Based on a manager's perspective, working with automated regression testing becomes less interesting for people since engineers engage in the same activity all the time, explains R2. In the long term, continues R2, it can be a problem because the employees are no longer comfortable at their workplace and may possibly leave it. This would mean the employment of new recruits and education in test areas which also requires resources such as time and money.

4.5 Improving the work flow

Once it is automated, claims R2, the number of units can be increased instead of just adding a test person and test equipment. It can take on several extensive test regressions that can be run all night, which according to R2 is positive. Sometimes organizations that for example use open source tools tend to isolate themselves because they download and use the tool, but they do not engage with the community, comments R4. So when they find errors they make quick fixes and avoid reaching out to the community, sometimes because of lack of time and sometimes because of internal policies regarding open source coming from legal departments. Further the interviewee R4 explains that this is an ineffective set up mainly for two reasons. According to R4, developers do not contribute to the development of the tool, since they neither report the errors they find nor share the fixes they make, thus not contributing to the community. On the other hand, this approach makes their version of the tool increasingly different from the one being implemented in the community, which makes it very costly to upgrade to newer and better versions coming from the community, claims R4.

"Absolutely it can be improved", says R2.

The interviewees agree that a crucial part of the continuous improvement of working with automation regression testing and its execution is trying to minimize errors as much as possible. Even if it has become a quite mature system, it takes a lot of time to know which type of error it is about, therefore it is important to continue developing it, comments R3. The interviewee R2 continues to explain that it is not necessary to add more people, the problem is that it is difficult to determine if the fails are coming from the test environment or if it is a software error.

"To determine it in black or white is really hard", argues R3.

Interviewees R3-R6 mean that it still requires many people to go through all the logs and maintain all test parts and improving it. For example, getting 198 passes and 3 errors is positive, but the nature of the problems is unknown. Then, questions related to those 3 issues are demanding an answer in the moment, e. g. if the problems belong to the software or the hardware, if it is because the timing issues or if it is too cold or too warm in the test room. According to R3, it is possible to get clear responses from the system regarding "pass/fail", but there are many devices and staff involved in the process, so it is difficult to determine exactly the errors' source is.

4.6 Important aspects in execution of automated regression test

Crucial aspects within the area has been identified by the interviewees as shown in the table 5.

Table 5. “Crucial steps in execution of automated regression test”

| Aspect | Explanation | Perspective | Respondent |
|---|---|------------------------|------------|
| 1.To have a person responsible for the system | -Regardless how much automation you have, it must be someone who knows the system. -It has to do with the capacity, equipment to test that it is supposed to have those investments from the beginning. | Management | R2 |
| 2.Easily get an overview of the test results | -Means to compare the days' results with previous software's test results to ensure that any information does not get missed due to not knowing what have been made the day before. -Information about the error from the scanning of the day before must to be available. | Engineering and Tester | R3, R1 |
| 3. Regular reconsideration of the cases. | -Test cases should be reevaluated when: (a) a function is not used often or not prioritized as important and (b) if the software is changed rapidly | Tester | R1,R5 |
| 4. Software validation needs to be in balance with all the other relevant pieces of the project. | -Needs to be made in order to emphasize the importance of understanding the software quality level required. -It cannot be expected that a software developer to implement a feature in a day of work, and then spend two extra days running tests (regression or any other type of testing) to make sure nothing has been broken. This affects not only the development pace negatively, but also creates frustration, sometimes even leading to ways to shortcut or even avoid test processes. | Engineering | R4 |
| 5.The system must be reliable | -If the system is not stable enough (that crash), it leads to many test cases that are not stable because it provides uncertain results and concern for the testers. -the system must be stable enough that it does not allow half-made test cases, all has to be written in the same mode otherwise it will be chaos. | Test Leader | R6 |
| 6. Access and control | - Only a limited number of skilled staff has access to the test environment. -Any upgrade done to the test environment is performed under controlled conditions and verified once completed. -Keep a backup of the environment before the upgrade, in case it fails, and compare results before and after upgrade using a known hardware and/or software under test, as a verification that the upgrade was successful. -Include the results after the upgrade and any issue to be solved, in case it was decided not to roll back the changes. -Use at least one means of distribution of information to notify all the users of the test environment. | Engineering/ Manager | R7 |

4.7 Identified steps based on empirical data

In the same manner such as in the section 3.5, the author of this thesis has created a model in order to summarize relevant collected data. In this section, the model shows an overview of how companies work within the domain of execution of automated regression testing, based on the empirical data collected by interviewing seven experts.

The model is designed as follow: on the left, there are three boxes that represent the three general categories of the model. They are *Test Execution*, *Regression Test* and *Automated Regression Test*. Each category contains crucial aspects identified by the interviewees about the selected theme. The big arrow behind the boxes indicate that they are the input of the outline shown on the right side of the model. Then, *Identified Steps* are the output of the model, where six stages were selected based on the model's input. In this case, many aspects coincide from interviewee to interviewee, and therefore the most important steps have been selected.(see figure 4)

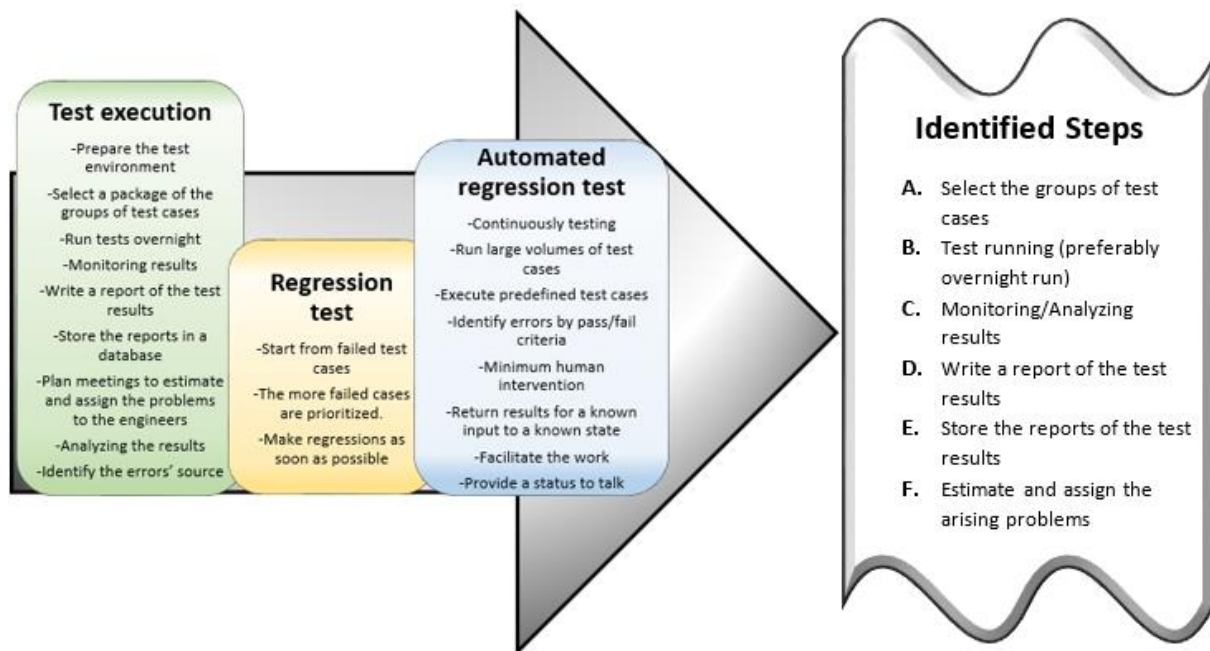


Figure 4. "Steps identified during the empirical study".

Steps identified during the empirical study:

1. *Select the groups of test cases*: the test cases are already predefined, so select the ones that are relevant to the specific test.
2. *Test running*: it is straightforward after the test selection and it should be run during the night.
3. *Monitoring/Analyzing results*: important to differentiate if the failures are from the software in testing or from the test environment.
4. *Write a report of the test results*: it must to be done regardless the nature of the error.
5. *Store the reports in a database*: refers to saving test result reports in order to get statistics about the error's cause and frequency, but also to analyze the stability of the test environment.
6. *Estimate and assign the arising problems*: it is crucial to assign the main problems to the correct experts as quickly as possible.

5. Analysis

5.1 Comparing the identified steps

In section 2.4, six stages based on the literature review and related to how to work with execution of automated regression testing have been listed (see figure 1). Simultaneously, other six stages from the empirical study has been identified, which are shown in section 4.7 (see figure 4). In the following section, phases from both models (figure 1 and figure 4) are compared and discussed in order to create a base for the presentation of the proposed framework shown in section 5.2 (see figure 5). The steps from theories are labeled with numbers from 1-6 while the steps from the empirical study are represented by letters from A-F.

Steps from the “*Steps identified from the literature review*” model:

1. **Validate the environment:** According to [24], it is crucial to check that the test environment matches the configurations required to the specific tests. It should be done in order to avoid that the test will not work properly or that wrong data will be provided [24]. However, according to the interviewees from the empirical study, to validate the test environment is not a part of the testers’ daily tasks in general. Other teams of experts are responsible for this activity. It can be experts from the same company, in case of “in house developed” test tools, but also from supplier companies, in the case that the test environment is purchased. Often the test suites related to test that are being done are purchased standards. Therefore how the automated test environment is configured with the specific test suites to use are decisions made at higher levels in the company, such as technical managers or managers in general. Thus, what literature suggests does not fit the practical experiences of testers that directly work with the execution of the automated regression test. In addition, the goal of the comparison of both kinds of steps is to generate a general framework to be used by testers. Therefore, the step “Validate the environment” has not been selected as a stage of the new model presented in section 5.2, “Proposed Framework for automated regression test execution”.
2. **Select test cases:** Researchers claim that in automated regression tests, test cases are produced by test case generator [20] and its selection depends on what the existing test period includes [19, 26]. According to the seven interviewees, this stage must be completed before tests can be run. Even if the norms for the test case selection differs between companies, it is the first step when working with execution of automated regression test. The most important is to center on testing functions based on the requirements or specifications. Thus, the step “*Select test cases*” that corresponds stage **A. Select the groups of test cases** from “*Steps identified during the empirical study*” model (see figure 4), is consistent with researchers’ opinion within the domain. Thereby this stage is considered as a crucial part of the “Proposed Framework for automated regression test execution” model.
3. **Execute/run tests:** To run a test in an automatic manner is relatively simple based on that test cases are already well-prepared or sensitized [18]. Researchers agree that how well the process of running tests flows are particularly dependent on the tools and the test environment used, but also

on the project context [24, 25]. This is important in order to ensure that any failures do not block the execution of other test cases [18, 24]. Other experts argue that the notion of a test passing or failing is related to the ability of the test driver to execute all specified test cases successfully [34]. Those assumptions match what the empirical study show, where running tests is described as the execution of a set of predefined test or set of tests. Entire collections of regression tests run during the night which allow that test results are enabled the next working day. Therefore, the stage “*Execute/run tests*” that is consistent with phase **B. Test running** from figure 4, has been selected as the second phase of the “Proposed Framework for automated regression test execution” model.

4. **Examine the execution report and fix bugs:** After the tests run, it generates an automatic result which indicate if the test has been failed or passed [20]. Those results need to be analyzed in order to define the error’s source [18, 19, 24]. Furthermore, researchers claim that the reports’ status should be prioritized daily [18]. Tian [18] argues that blocking issues should be resolved as soon as they arise, which also is supported by [19, 24]. Those theories agree with interviewees’ experiences, which is shown in figure 4, stage **C. Monitoring/Analyzing results**. They argue that it is crucial to differentiate if the failures are due to the software being tested or due to the test environment. At the same time, the unsuccessful test runs again and if the failure persists, main problems are assigned to corresponding departments for exploration and rectification. In short, this stage has been taken in account to create “Proposed Framework for automated regression test execution” model, but instead it has been adopted to the name of stage **C** from figure 4 in order to use a term that is well-known among testers.
5. **Archive tests:** According to [19, 24], test data and test result reports may be archived in order to have a basis for further analysis of the nature of test failures and how often they occur. It depends on the team to decide which method and where it is best to save those results, e. g. copies saved into dated folders on a database [19]. These statements have directly been evaluated based on interviewees criteria from the empirical study shown in chapter 4 and that match the stage **E. Store the reports in a database** from figure 4. They claim that in their companies, all results, with fail and pass verdict are stored in a database. By doing that the managers or test leaders can create statistics that can help them to take decisions about how to proceed, for example if it is worth to continue using the same environment or not. Thus, this phase, “*Archive test*”, is considered important to testers work with execution of automated regression testing and therefore is the fifth step of the “Proposed Framework for automated regression test execution” model.
6. **Manage the test cycle:** To manage test cycles, it is important to eliminate unrealizable tests in reverse-priority, the lowest first and the highest last [18, 19]. Test cycles include the selection of a test suit, where often a subset runs against a particular test release [19]. Regular reexamination of the case test are needed in order to reconsider or eliminate functions that are not used often or not prioritized as important [19]. Related to this stage, interviewees argue that if the software is changed frequently the maintenance of the test cases

needs to be done regularly. Also, if using automated test cases new defects on different functional areas, it will not be found unless there is a conscious update of the test suite and therefore it is crucial to reconsider them often. Even if only two of seven interviewees refers to this stage, “*Manage the test cycle*” has been taken in account to create the “Proposed Framework for automated regression test execution” model. Thus, in order to bring experts from other companies a new point of view to improve their work manner to execute automated regression testing.

Steps from the “*Steps identified during the empirical study*” model:

D. Write a report of the test results and **F. Estimate and assign the arising problems**: These two stages come from the model “*Steps identified during the empirical study*” (see figure 4) and have been identified by the interviewees as crucial phases in working with execution of automated regression testing. An internal report of test results that include test failure descriptions should be done which allow developers to be able to go forth with the issues. Furthermore, the issues identified need to be estimated and consigned to the proper team or department to solve it. Those steps are missing in the model “*Steps identified from the literature review*” (see figure 1). Therefore it is necessary to incorporate them into the “Proposed Framework for automated regression test execution” model in order to continue improving testers’ actual working flow.

In summary: After comparing and analyzing the above stages from theories and the empirical study, the step **1. Validate the environment** from “*Steps identified from the literature review*” model (see section 2.4) is not consistent with experts’ practical experiences in working with execution of automated regression test. However, the following four steps, from 2-5, matches each other, while the phase **6. Manage the test cycle** is considered as a relatively new because the literature does not discuss much about the theme and only two interviewees briefly mention it. In addition, the last two phases discussed **D. Write a report of the test results** and **F. Estimate and assign the arising problems** belonging to “*Steps identified during the empirical study*” model (see section 4.7) do not have support in the “*Steps identified from the literature review*” model (see section 2.4). Thereby, those changes are a complement to testers’ actual work flow within the domain of execution of automated regression testing.

5.2 The proposed framework

As explained in the previous section, the comparison between the “*Steps identified from the literature review*” from section 2.4 and the “*Steps identified during the empirical study*” from section 4.7 are the pillars to the new model called the “Proposed Framework for automated regression test execution” (see figure 5). The model is a complement to how testers work with execution of automated regression testing in general. It includes seven stages to follow which are explained in detail.

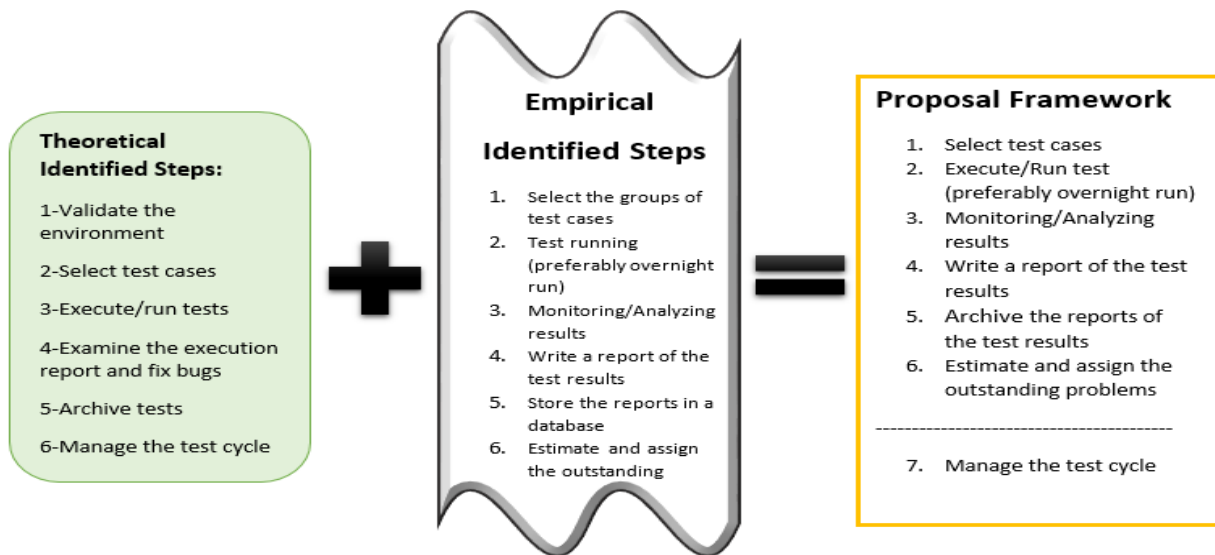


Figure 5. "Proposed Framework for automated regression test execution"

Steps for the implementation of the proposal framework for automated regression test execution:

To implement this framework, it is important to analyze the particular situation of the product that is being tested and the specific needs of the company. Testers should identify which test cases need to be tested according to the product requirements and a suitable test environment. Then, the steps below should be followed:

1. *Select test cases:* the test cases are already predefined, so select the ones that are relevant to the specific test or that apply to the current test phase.
2. *Execute/Run tests:* After the test selection, it is straightforward with the execution of the test, but it should be done preferably during a time when the test environment is used the least, e. g. during the night. Running tests also depends on the specific tools that are used during the test where the most important is to ensure that failure do not block the execution of other test cases [18, 24].
3. *Monitoring/Analyzing results:* when the test results are available, they need to be analyzed to determine the errors' source and the solution [18, 19, 24]. Therefore, it is important to differentiate if the failures come from the software in testing or from the test environment.
4. *Write a report of the test results:* this must to be done regardless of the nature of the error of the executed test. The report's content may vary depending of what kind of information the company is interested to save. As an example, a report could contain the verdict of the test (pass/fail), the logs of the execution which include all the information recorded during the test execution, the version of the software under test and version of the test executed. Companies can use a template for test report, like the ones provided by RUP or UPEDU [38] or the companies can design their own test report template.
5. *Archive the reports of the test results:* refers to the saving of test result reports in databases or other storage devices in order to get statistics about the error's cause and frequency [19, 24]. But it is also a basis for further analysis of, e.g. the stability of the test environment. Tests often cannot be generalized and therefore it is crucial to keep results for further analysis [33].

6. *Estimate and assign the raised problems*: it is crucial to assign the main problems to the correct experts as quickly as possible in order to minimize the delivery time of fixing bugs.
7. *Manage the test cycle*: it is shown in the model as an optional stage and should be done in order to remove unrealizable tests. This process should be done in reverse-priority where the less important test eliminates first and the highest last [18, 19]. With test cycles it means the selection of a test suit, where often a subset run against a particular test release [18, 19].

5.3 Critical discussion of the proposed framework

The crucial part of the overall test execution is the smooth transition from one test run to another, which also requires to allocate all the resources to ensure that individual test runs can be started, executed, and finished [18, 22]. At the same time, problems related to test running can be handled seamlessly [18]. In this case, the “Proposed Framework for automated regression test execution” model is an important work process that allows the improvement of testers’ working flow with execution of automated regression testing. The new model is complementing based on that it has a newly added phase (*7.Manage the test cycle*). Another stage (*Validate the environment*) from literature has been removed due to it is not suitable for tester’s daily work within this domain of execution of automated regression testing. In addition, two other steps (*Write a report of the test results and Estimate and assign the arising problems*) that actually are being used in some companies have also been included in the proposed model, in order to support testers’ work in general.

The new added step can give companies a new point of view about how to increase the effectiveness of the available resources by reconsidering test cases, which according to Harrold [33] inspires confidence. Companies always should have the opportunity to re-evaluate the process or framework in which testers are working and as well adjusting it. Probably testers will not go through this step every single test cycle, due to e. g. changes made because of the implementation of new features of the product that is being tested. But it is important to conduct a new evaluation of the test selected often. It can also reduce the list of test cases and therefore the amount of the time using during execution of regressions which according to [35] reduces the cost of regression testing. In this way, it could be avoided that tests groups remain intact during the regression tests.

By applying the “Proposed Framework for automated regression test execution” model in working with execution of automated regression testing, risk analysis could be done in order to choose the correct set of test cases. A risk analysis reduces the threat of failure [1]. By doing a risk analysis, deficiencies in selecting test cases could be solved or avoided, which is the starting point of the framework.

6. Conclusions and future work

6.1 Conclusions

This paper has identified several stages for working with execution of automated regression test from two perspectives: what the literature discuss and an empirical study. Those steps have been compared and analyzed in order to create a general, updated and complementary framework to improve testers daily work flow. It has been grounded on the two research questions of this study:

RQ1: *The current routines for working with execution of automated regression test* that have been listed according to the literature are presented in “*Steps identified from the literature review*” model (section 2.4, figure 1) and consist in six stages: (1) *Validate the environment*, (2) *Select test cases*, (3) *Execute/run tests*, (4) *Examine the execution report and fix bugs*, (5) *Archive tests*, and (6) *Manage the test cycle*. Related to the practical perspective, another model has been created, “*Steps identified during the empirical study*” (section 4.7, figure 4). It includes six stages: (A) *Select the groups of test cases*, (B) *Test running*, (C) *Monitoring/Analyzing results*, (D) *Write a report of the test results*, (E) *Store the reports in a database*, and (F) *Estimate and assign the arising problems*.

RQ2: *To improve the current routines* a new framework has been created based on the above comparison. The model is named “*Proposed Framework for automated regression test execution*” (see section 5.2, figure 5) and implies seven phases: (1) *Select test cases*, (2) *Execute/Run tests*, (3) *Monitoring/Analyzing results* (4) *Write a report of the test results* (5) *Archive the reports of the test results* (6) *Estimate and assign the outstanding problems* and (7) *Manage the test cycle*.

Important findings have been made as a result of the comparison of both kinds of identified steps, thus in “*Steps identified from the literature review*” and “*Steps identified during the empirical study*”. First, to validate the test environment is not applicable for testers’ daily working tasks within the domain of execution of automated regression testing. This assignment is the responsibility of others experts, either from the same company or from suppliers of the test environment. The second finding refers to the stage “*Manage the test cycle*” that has been considered as a new phase in order to improve testers’ actual work flow. The third finding consists in that four stages proposed in theories (see stages 2-5, section 5.1) do not differ from the interviewees’ practical experiences. Last and not least, the steps “*Write a report of the test results*” and “*Estimate and assign the arising problems*” have been identified from the empirical study and they do not have support in theories from the “*Steps identified from the literature review*” model.

In addition, several important aspects in working with automated regression testing (see section 4.6) have been identified, related to systems stability, software validation and to have a person responsible for the system. Those issues involve decisions at higher levels within the companies such as technical managers or managers in general. This is not a task that testers have to handle in their daily work. Therefore it is not considered as a part of the developed work process, thus “*Proposed Framework for automated regression test execution*” model.

6.2 Future work

Due to the selected interviewees that did not answer questions related to the validation of the *"Proposed Framework for automated regression test execution"* model, in a specified period of time, it has not been possible to implement this part in the study. Therefore, the author of this report strongly recommends for future work in which this new model needs to be tested. Furthermore, the following questions related to the theme have been identified:

- What are the challenges of applying the model *"Proposed Framework for automated regression test execution"* in large companies within the domain of execution of automated regression testing?
- Is it possible to establish the *"Proposed Framework for automated regression test execution"* model in smaller companies within the domain of execution of automated regression testing?
- How much effort those companies save by applying the *"Proposed Framework for automated regression test execution"* model?
- Can testers from different companies within the domain of execution of automated regression testing, work successfully by following the *"Proposed Framework for automated regression test execution"* model?
- Would it be possible to analyze the results from applying the *"Proposed Framework for automated regression test execution"* model in order to improve regression testing in future projects?

Another recommendation for future work concentrates on validating the *"Proposed Framework for automated regression test execution"* model by applying it on several companies simultaneously in order to analyze how effective it could be. Furthermore, an extension of the *"Proposed Framework for automated regression test execution"* model can be made from a management point of view where important considerations should be done, e. g. related to decisions about systems stability, software validation and to have a person responsible for the system.

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Appendix

A1. Interview questions

1. Can you describe your work? Example: the input and output, the processes and tools used.
2. How would you personally define automated regression testing?
3. For how long have you been working with automated regression testing?
4. Do you have some specific activities or framework you follow to work with execution of automated regression test?
 - a) If not, please could you explain how do you work with automated regression test and its execution?
5. What tools do you use for the automated regression testing?
6. What advantages are there with the current activities/framework for execution of automated regression testing?
7. What disadvantages are there with the current activities/framework for execution of automated regression testing?
8. How do you think these activities/framework can be improved for the execution of automated regression testing?
9. Are there any aspect/steps that you realize is "a must" when working with the execution of automated regression testing?
10. Is there anything you would like to add what we have said?