

# A Systematic Literature Review of Automated Software Testing Tool



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**Abstract** Automated software testing has proven its value for software development increasingly over the past few years. Software testing is an important phase in the entire software development process. There are various automated software testing tools available today, which are used for testing various software applications whether it is desktop-based, mobile application, or a Web-based application. Evaluating a software testing tool is rather a subjective task, depending on the evaluator's opinions rather than based on the objective approach. For this purpose, we have studied research papers, articles, journals, books, conference papers, few Web sites, etc., related with the study of software testing tools based on which we performed a survey of various automated software testing tools, i.e., Selenium, Watir, QTP, Test-Complete, WinRunner, LoadRunner, SilkTest, Apache Jmeter, Wapt, Tellurium, Web Load, NeoLoad, LoadUI, Appvance, rational performance tester, SahiPro, Telerik Test Studio, Ranorex, Storm, Soap UI, TestNG, FitNesse, Xebium, etc. The purpose of this research work is to summarize the existing literature and to establish an overview of the existing automated software testing tool to benefit the practice of users and for future research. We are attempting to provide detailed insight into automated software testing tools which can help the tester to choose the tool most suited to test his/her application.

**Keywords** Automated · Software testing · Selenium · Software development · Testing tool · Web-based application

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## Abbreviations

QTP	QuickTest professional
IDE	Integrated development environment
RC	Remote control
API	Application program interface

## 1 Introduction

The software testing process intends to distinguish all the imperfections existing in a software. Testing is no longer observed as a movement that begins simply after the coding stage, it ought to be inescapable all through the product advancement life cycle. Testing is a lot of exercises that can be arranged and directed deliberately [1]. It is the way toward accessing a framework or system parts by manual or programmed intends to confirm that it fulfills expected requirements or not. It additionally distinguishes the contrasts among expected and genuine outcomes.

Testing can be done by using automated software testing tools, which is also known as test automation tools [2] is when the tester writes scripts and uses another software to test the software. It can perform load, execution, practical and stress testing, and so on. It improves precision and sets aside time and cash in contrast with manual testing. Manual testing requires many labor-intensive tasks, running numerous program executions, and handling a great amount of information. Testing often consumes 40-50% of development efforts, and it consumes more effort for systems that require a higher level of reliability [3]. So, it will give rise to the demand for automated software testing tools. Appropriate tools can alleviate the burden of clerical, tedious operations and make them less error-prone. Sophisticated tools can support test design and test case generation, making it more effective. Direction to supervisors and analyzers on the best way to choose testing apparatuses that will be generally helpful to their association and experts is significant, as device determination extraordinarily influences testing productivity and viability.

We proceed with this paper with our writing study in which we have characterized and investigated many softwares (e.g., Selenium testing tool, Watir, QTP, TestComplete, WinRunner, Load Runner, SilkTest, Apache Jmeter, Wapt, Tellurium, Web Load, Neo Load, LoadUI, Appvance, rational performance tester, SahiPro, Telerik Test- Studio, Ranorex) dependent on different software quality attributes like understandability, modifiability, modularity, cost-effectiveness, extendibility, reliability, flexibility, reusability, browser compatibility, and OS compatibility [4-8].

Analysis of automated software testing tool gives administrators and analyzers understanding that can drive significant choices in regards to device determination for their undertaking. This data will give a superior comprehension of the apparatuses. As there are different automated testing tools which have different element yet despite the fact that they likewise have hardly any restrictions. This makes them monotonous

to use for testing. There is a prerequisite of such a device that can be demonstrated its capability to do the entire testing process in less time, costs less cash, and needs less exertion and labor.

This paper will further contain Sect. 2 as a review methodology that describes the method adopted for the literature review. The literature review is described in Sect. 3. Further, the result of review work is presented in Sect. 4, and Sect. 5 presented the conclusion of all the above work.

## 2 Literature Review

The literature review was done to establish an understanding of the state of research in the area of automated testing tool, and the goal is to address the existing research done for automated testing tools and to present results related to these. The literature review represented in this paper is such that which identifies publications of relevance, evaluates, and selects publications for review and organizes them such that common concepts are identified and structured manuscript in different sections.

Anju Bansal [1] presented details of the flow of test information while testing an application. It also represents a different form of black box testing, white box testing, and gray box testing. Software testing can provide an independent view of the software to allow the business to appreciate and understand the risk of software implementation. This paper also provides the detailed insight into types of testing along with their advantages and disadvantages. With black box testing, one need not to have knowledge of programming language, testing can be done from user point of view, but test case is very hard to design, and some part of the backend is not tested at all. Apart from black box testing, white box testing focuses on the internal logic of code, it helps in uncovering the error from the code, but for this task, skilled testers are needed, and it is very tedious and time-consuming. While the third type, i.e., gray box testing generally combines the benefits of both types of black and white box testing.

A framework based on Selenium WebDriver and TestNG is proposed by Satish Gojare, Rahul Joshi, and Dhanashree Gaigaware [2]. As Selenium has a lack of customized report generation facility, therefore the author proposed a framework which is used to generate the customized report. The component of the proposed framework is object repository which performs the task of maintaining and repairing test cases, the input file will contain the input required by the web pages under test, and the utility section contains web page-related functions. Test suite can be formed by taking input from these three component object repository, input file, and utility file. Above all these, the test result after running the test suite can be fed to TestNG unit which will then generate a test report.

Quality of software system is defined based on quality attributes such as portability, reusability, interoperability, reliability, and performance. Software systems are checked based on their quality. Therefore, the quality characteristics are considered to be very important during the development of software. Therefore, Ritika Vern

and Sanjay Kumar Dubey [4] present a study of few quality characteristics based on fuzzy logic technique. This will help the researcher, developer, and tester to decide their perspective in the area of software quality.

The quality attribute is required to capture how the functional requirement of an application is achieved. To trace the quality of the software, the quality attribute plays a very important role. Gorton, essential software architecture [6], gives a description of various quality attributes which helps to capture the quality of software, and it also sets a comparison criteria for comparing various software.

SWEBOK V3.0, [8] a guide to the software engineering body of knowledge Chap. 4 software testing, this chapter will represent the importance of software testing as a part of software development, and it also describes the basic terminologies and software quality-related attributes like maintainability, portability, usability, etc.

Nisha Gogna [9] talked about the most basic features of browser-based automation testing tool, i.e., Watir and Selenium. In this paper, the author describes mainly the details of components of Selenium such as Selenium IDE, Selenium RC, and the Selenium Grid. According to which, Selenium IDE is the integrated development environment used for preparing test cases and is used as Firefox add-ons. Firefox has many add-ons to be used with Selenium IDE which will increase its usability. The author also described briefly about Selenium RC, according to which the developer has to use programming language for writing test script to get maximum flexibility and extendibility. The Selenium Grid is another component of Selenium testing tool which scales the use of Selenium RC on multiple platforms and on multiple browsers. This paper also gives the details of the platform, browser, and languages supported by the Selenium testing tool. Also, Selenium has a deep learning curve to switch from one component to another as compared to Watir.

Based on the study of Selenium RC and Selenium WebDriver, the author Mahan Sunhare, Abhishek Tiwari [10] found that the architecture of Selenium RC is more complicated as compared to Selenium WebDriver and Selenium WebDriver has also friendlier API than Selenium RC. Software developers thought to build beautiful and attractive web pages, but they did not bother about their accessibility and presentation on various browsers. Therefore, the author describes the need of focusing on browser compatibility issue for a consistent look of web pages on all browsers.

In this paper, the author, Shaukat [11], presents the taxonomy of various automated software testing tools along with the importance of software testing methods as a part of the software development life cycle (SDLC). The author's perspective is to present with a comparative study of various automated software testing tools such that one can get a brief overview of all the tools presented in the paper. The tools which are chosen for comparative study are Selenium, Watir, Sahi Pro, HP-QTP, TestComplete, Ranorex, NeoLoad, hp LoadRunner, FitNesse, SilkTest, TestNG, Apache Jmeter, Soap UI, Tellurium, WebTest, Xebium, Wapt, WebLoad Testanywhere, LoadUI, Appvance, rational performance tester, Visual Studio, and Telerik Test Studio. All these tools are studied based on operating system support, browser support, application used for testing, language support, cost-effectiveness, etc.

A study on various open source automated testing tools and a brief comparison of the same based on application support, language support, platform support, and

understandability is presented in the paper by the author Bhat and Chaudhary [12]. Based on the survey, it is found that some of open source tools have some limitations while a commercial one has some good features. Therefore, the selection of the tool is completely based on the project needs and testers knowledge. According to the study of this paper, among all studied tools, Selenium has support for vast programming languages and platforms.

Chandraprabha et al. [13] talked about the systematic study of Selenium testing tool with all its components, architecture, and limitations also. As Selenium is an open source automated Web testing tools and being component-based, it is used by most of the testers. According to the study, automated testing is very advantageous as it saves time, money, and effort. It is also reliable and improves the accuracy of the testing process. Along with the details of the Selenium testing tool's component, the author also talked about the limitations of the component. According to which, the main feature of Selenium IDE is easy to record and playback, support autocomplete command, customization is allowed through plug-ins, allow to set breakpoints and debug the script, but apart from all these features, it has few limitations as it can be only used as a Firefox plug-ins, it has its own language Selenese. With Selenium RC, it is possible to run tests inside every JavaScript compatible browser using a wide range of programming language. On contrary to this feature, it is slow, struggles while running concurrent tests, and does not allow simultaneously tests across different OS and browsers. But with the help of Selenium Grid, one can run test cases across all browsers. Selenium WebDriver being a robust, open source, cost-effective and widely used tool cannot readily support new browsers.

Altaf et al. [14] specify all the pros and cons of every component of the Selenium testing tool. Selenium is a freeware open source testing tool. There are many challenges with it, and the main is that it has drawbacks, the user interface is slow for many reasons.

Mustafa et al. [15] had discussed about sets of software testing tool and classify them over the types of testing they can perform. Here, stress, load, regression, functional, unit, performance, and security testing are defined. The author had also represented the result of his/her study through the graph. One graphical representation specifies the type of application which is mostly tested, and the result shows that Web application widely tested by using software testing tool. There is another graph that shows a widely performed type of testing, and the result shows that functional testing is widely performed on applications.

### 3 Result of Literature Review

This section presents a brief study of most widely used testing tools based on literature review, which includes various testing tools. Individual tools such as Selenium testing tool, Watir, QTP, TestComplete, WinRunner, LoadRunner, SilkTest, Apache Jmeter, Wapt, Tellurium, Web Load, Neo Load, LoadUI, Appvance, rational performance tester, SahiPro, Telerik Test Studio, Ranorex are classified in Table 1 which represents

**Table 1** Classification of automated software testing tools

Tool name	Developer (describes the developer's name)	OS support (describes about the operating system supported by the tool)	Browser support (describes about the browser supported by the tool)	Application support (describes about the application tested by tool)	Testing type (describes about the type of testing performed by the tool) [30]	Language support (describes the language supported by the tool)	Open source/A commercial (specifies whether the tool is open source or not)
Selenium [9–12, 16, 17]	Developed by Jason Huggins in 2004	All platform	All major browser	Web application [28]	Integration, regression testing and functional testing	Java, C#, PHP, Ruby, Python, Perl	Open source
Watir [9, 11, 12, 18, 19]	Developed by Bret Pettichord and Paul Rogers	Cross platform (Windows, Linux)	Internet Explorer, Opera, Firefox	Web application	Regression testing and functional testing	Java, .Net, C#	Open source
Test complete [11, 16, 18–20, 33]	Developed by Smart Bear Software In. in 1999	Windows	IE, Firefox, Chrome	Desktop web and mobile applications	Regression testing and functional testing	Vbscript, Javascript, C++, Delphiscript	A commercial
QTP [11, 19, 21–23, 35]	Developed by HP in 2001	Windows Xp	IE, Firefox, Chrome	Client server application (Web)	Regression testing and functional testing	Java, Vbscript, JavaScript	A commercial
Win Runner [11]	Developed by HP	Windows, Linux	IE, Netscape	Web application	Load testing	SL Test scripting language	A commercial
Silktest [11]	Developed by Segue Software In. in 1993	Windows	IE, Firefox,	Web hybrid and Native application	Regression testing and functional testing	Java, VB, C#, VB.NET	A commercial

(continued)

**Table 1** (continued)

Tool name	Developer (describes the developer's name)	OS support (describes about the operating system supported by the tool)	Browser support (describes about the browser supported by the tool)	Application support (describes about the application tested by tool)	Testing type (describes about the type of testing performed by the tool) [30]	Language support (describes the language supported by the tool)	Open source/A commercial (specifies whether the tool is open source or not)
LoadRunner [11, 19, 24]	Developed by HP in 1989	Windows, Linux, MAC	Any browser	Web application	Load testing	Java, VB, C#, Vbscript, JavaScript, C	A commercial
Apache Jmeter [11, 24]	Developed by Apache software foundation in 1998	Unix, Windows	Chrome	Web application	Load testing	Java	Open source
Wapt [11, 24]	Softlogic	Windows, Unix	IE, Firefox, Chrome	Web, Mobile application	Load and stress testing	Asp.Net	Open source
Tellurium [11, 18, 19]	Developed by Jian Fang in 2007	Windows, MAC, Unix	All browser, Android, Blackberry	Web application	Load and performance testing	Java, Groovy	Open source
Web load [11, 24]	Developed by Redview Software in 1997	Windows, Linux, Unix	IE, Firefox, Chrome	Web, Mobile application	Load and performance testing	Java, JavaScript, .Net, PHP	Open source
Neo Load [11, 19, 24]	Developed by Neotys in 2005	Windows, Linux, Solaris	Chrome, Firefox	Web, Mobile application	Load and performance testing	JavaScript, .Net, PHP	A commercial

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Table 1 (continued)

Tool name	Developer (describes the developer's name)	OS support (describes about the operating system supported by the tool)	Browser support (describes about the browser supported by the tool)	Application support (describes about the application tested by tool)	Testing type (describes about the type of testing performed by the tool) [30]	Language support (describes the language supported by the tool)	Open source/A commercial (specifies whether the tool is open source or not)
Load UI [11, 24]	Developed by Smart Bear Software In. in 2010	Windows, Linux, MAC	Chrome , Firefox	Web, Mobile application	Load and performance testing	Java, Javafx, Groovy	Open source
Appvance [11, 24]	Appvance Inc.	All platform	All browser web and mobile also	Web and Mobile application	Function and performance testing	PHP, Perl, Python, Groovy, Ruby, C#, Java	Open source
Rational performance tester [11, 24]	IBM	Linux, Windows	IE, Chrome, Firefox	Web and Server application	Data-driven and performance testing	Java	A commercial
Sahi Pro [11, 18, 19, 24]	Developed by Sahi in 2005	All platform	IE, Firefox	Web application	Data-driven testing	Java, PHP, Java Script, Python	A commercial
Telerik test studio [11]	Telerik	Windows	All browser	Web application and desktop application	Performance, data-driven and functional testing	C#, .Net	A commercial
Ranorex [11, 19, 20, 34]	Ranorex GmbH	Windows	Opera, Firefox, Netscape, IE, Chrome	Desktop web and Mobile applications	Function testing	Java, Html, C#, Android	Open source



the basic details of tools such as developer's name, year in which the tool is initially developed, OS support, browser support, application support, testing type, language support and whether the tools is open source or a commercial.

All the above-mentioned automated software testing tools are compared based on software quality attributes like understandability, modifiability, modularity, cost-effectiveness, extendibility, reliability, flexibility, browser compatibility, OS compatibility [4–8].

### ***3.1 Software Quality Attributes***

The detailed definition of all the above-mentioned software quality attributes is listed below, and their comparison based on these attributes is given in Table 2.

1. **Modifiability:** This defines the ability of software testing tool of being modified according to user requirement [4, 6].
2. **Understandability:** It is the attribute that determines how easy is the tool to be used without the need for expertise [4].
3. **Extendibility:** It defines the degree to that software should be extended, i.e., functionalities should be added to the existing software [7].
4. **Modularity:** It is the degree to which a system's component may be separated [7].
5. **Compatibility:** It is the usability of the same software in different environments (like different OS, browsers, etc.) [7].
6. **Cost-effectiveness:** It is the attribute that tells us whether the software is freely available to the user or there is purchasing cost associated with it [7].
7. **Flexibility:** It is the degree of ease with which a system can respond to any change [4].
8. **Reliability:** It is the degree to which the result of testing should be accurate or consistent. [4].

## **4 Conclusion**

In total, from the survey and reviewed literature, we found that the tool selection depends on diverse evidence, such as development choices, evaluation objectives, execution facilities, and on so many parameters. In general, there may not be a unique tool that will satisfy particular needs, so maybe a suite of tools would be an appropriate choice. So, it gives us motivation to classify automated software testing tools and study them to explore their features and limitations. Analysis of automated software testing tool provides managers and testers insight that can drive important decisions regarding tool selection for their task. This information will provide a better understanding of the tools. As there are various automated software testing tools available which have various feature, but although they also have few limitations.

**Table 2** Comparison of automated software testing tool based on software quality attributes

Tool name/year/version released in that year	Understandability	Modifiability	Flexibility	Extendibility	Modularity	Cost-effectiveness	Reliability	Browser compatibility	OS compatibility
Selenium [9–12, 16, 17, 27]	Test reports are relatively easy to understand	It is modifiable	It can withstand the changes made in it	Selenium IDE supports a wide range of extensions to enhance the capabilities of the core tool, thereby multiplying its potential	It has adopted modular approach for its development	Freely available	Selenium offers a user-friendly interface that helps to create and execute test case easily and ensure reliability in terms of result	Selenium provides support across multiple browsers, namely Internet explorer, Chrome, Firefox, Opera, safari, etc	Selenium can operate and support across multiple operating systems (OS) like Windows, Mac, Linux, unix, etc
Selenium 2016 (version 2.49 to 3.0.0)	Improved report generation by using TestNG framework	It has capability to modify according to user requirement	It is flexible, i.e., respond well to the changes made in it	Support for wide range of extensions to improve performance but has limited support for browser extension	Modularity is supported by it, as it has various components	Freely available	It makes the testing result more reliable or consistent	Firefox is only supported till version 47.0.1 or earlier	Fully support all OS

(continued)

**Table 2** (continued)

Tool name/year/version released in that year	Understandability	Modifiability	Flexibility	Extendibility	Modularity	Cost-effectiveness	Reliability	Browser compatibility	OS compatibility
Selenium 2015 (version 2.46 to 2.48)	By improving easy output generation up to some extent, it also added support for enhanced screenshot capturing	It supports modifiability	It gives good response to the changes made by user or programmer	Support for various update of technologies but with few limitations like it does not support Firefox above 47.0.0	It supported modularity	Freely available	Yes, it generates accurate result, thus supporting reliability	Supported Firefox only up to 47.0.0 do not support newer versions and all remaining browsers	Fully support all OS
Selenium 2014 (version 2.40 to 2.45)	Improve understanding by removing unnecessary dependencies	It can be modified easily	It has feature to response to change	Updating gecko driver, thus improving browser capability	It supported modularity	Freely available	It ensures reliability to generate correct output	Support Firefox only up to 33 , improving Chrome facilities and support other browsers	Yes, fully support all OS

(continued)

**Table 2** (continued)

Tool name/year/version released in that year	Understandability	Modifiability	Flexibility	Extendibility	Modularity	Cost-effectiveness	Reliability	Browser compatibility	OS compatibility
Selenium 2013 (version 2.28 to 2.39)	Improved capability to take good screen shots	It supports to modify easily	It supports flexibility, i.e., quite easy to introduce any change	Improve extendibility by updating various driver supports for various browsers in the core tool	It supported modularity	Freely available	It has features that make testing more reliable	Support Firefox up to 26	Yes support Linux up to 24 versions , also added support for iphone driver
Selenium 2012 (version 2.16 to 2.27)	Improved error messages on console, support for hovering on Linux	It allows to modify few requirement according to user	Yes, it is easy to make changes in it	Test result can be extended, and it can be represented by test history	Supported modularity	Freely available	Yes, it makes testing more reliable	Support Firefox up to 17, update Opera to 0.15, and safari driver also added	It added support for hovering on Linux
Selenium 2011 (version 2.15 and before)	Improved by introducing screenshot capability	It is modifiable	Yes, it has capability to response well to changes	It support extendibility by updating various browser support	Supported modularity	Freely available	It ensures reliability to generate correct output in less time	Support only up to Firefox 11. Improved performance with Chrome and, i.e.	Yes (support for ice cream sandwich in the Android)

(continued)

**Table 2** (continued)

Tool name/year/version released in that year	Understandability	Modifiability	Flexibility	Extendibility	Modularity	Cost-effectiveness	Reliability	Browser compatibility	OS compatibility
Wair [9, 11, 12, 18, 19]	It allows writing the tests which are easy to read and maintain	It allows writing the tests which are easy to modify	It is simple and flexible but limited flexibility	Support extendibility partially	Modularity is not fully supported	It is a free open source tool	Yes, it is reliable tools	Wair classic supports only Internet Explorer (limited) on Windows; supports Firefox, Internet Explorer, Opera, Chrome and also runs in headless mode (html unit)	It supports Windows, Mac, and Linux
Wair 2016 Versions (6.0.0 to 6.0.3)	Quite easy (prior knowledge of scripting required)improved error message facility	It allows easy maintenance by making modification if required	It has limited support for flexibility	It supports extendibility up to certain extent only	Modularity is not fully supported	It is a free open source tool	It is reliable in terms of result generation	Added support for Chrome as default browser	It support Windows, Mac, and Linux

(continued)

**Table 2** (continued)

Tool name/year/version released in that year	Understandability	Modifiability	Flexibility	Extendibility	Modularity	Cost-effectiveness	Reliability	Browser compatibility	OS compatibility
Wair 2014 and 2015 Version (4.1.0 to 5.0.0)	Improved output facility and enhanced screenshot capability	It allows easy modification if required by user	It supports only few changes	It has limited support for addition of new features	Modularity is not fully supported	It is a free open source tool	It is reliable due to improved output generation	More flexibility with Internet Explorer and Firefox	It supports Windows, Mac, and Linux
Wair 2013 Version 3.4.0 to 4.0.1	Add capability to take screenshots	It ensures easy modification and thus removes unused processes	It responds well to few changes only	Added support for few technologies	Modularity is not fully supported	It is a free open source tool	It is reliable	Added support for Internet Explorer 10	It supports Windows, Mac, and Linux
Wair 2012 Version 3.0.0 to 3.3.0	Support for drag drop options	Modified by adding api support	It does not work well with major changes	This tool has limited support for extendibility	Modularity is not fully supported	It is a free open source tool	It makes testing process more reliable	Added support for opera	It supports Windows, Mac and Linux

(continued)

**Table 2** (continued)

Tool name/year/version released in that year	Understandability	Modifiability	Flexibility	Extendibility	Modularity	Cost-effectiveness	Reliability	Browser compatibility	OS compatibility
Waitir 2011 Version 1.7.0 to 2.0.4	Improved speed of execution of test cases	Remove unnecessary dependencies, thus ensuring easy modification	It has limited support for flexibility	Extendibility for fixed input values is added	Modularity is not fully supported	It is a free open source tool	Improved speed of execution of test cases making it more reliable and accurate	IE improvement and Firefox improvements	It supports Windows, Mac, and Linux
QTP/UFT [11, 19, 21–23, 35]	It is easy to use software for both people with or without programming knowledge	No, difficult to change	Difficult to change	Hard to extend	Support to modularity	Costly (not open source)	Yes it is reliable	Support multiple browser but not all (IE, Chrome, Firefox, safari)	Limited support
QTP/UFT 2016 Versions 12.54	Easy to use and work with this tool (improved drag and drop option)	Difficult to modify	Yes it supports flexibility but it is restricted as it is licensed	Functionality can be added but in limited manner	Yes it has modular approach for development	Not freely available	It is reliable as it produces the desired result	No support Chrome till version 54 and Firefox till version 49	Only support Windows system

(continued)

**Table 2** (continued)

Tool name/year/version released in that year	Understandability	Modifiability	Flexibility	Extendibility	Modularity	Cost-effectiveness	Reliability	Browser compatibility	OS compatibility
QTP/UFT 2015 Versions 12.5	Improved cross-browser testing , and now result can be shared without result viewer installation on other system	It supports modifiability but only by its original developer	Flexible up to some extent	Hard to extend because it is not open source	It has modular approach for development	Not freely available	It is reliable	Cross-browser testing is introduced	Only support Windows system
QTP/UFT 2014 Versions 12 to 12.02	Easy to learn, faster installer, better documentation	Costly to modify as it is a commercial tool	Not much flexible as it allows update up to certain extent	Hard to extend	Yes it has modular approach for development	Not freely available	It is reliable due to good output generation	Yes (support for safari browser)	Only support Windows system (added support for Windows 8.1)
QTP/UFT 2013 Versions 11.51, 11.52, 11.53	Good and UFT now fully supports .xlsx format.	Modifiability do not supported by users	Yes it supports flexibility, but it is restricted as it is licensed	Hard to extend because it is a commercial tool	Yes it has modular approach for development	Not freely available	Yes it is reliable	Added support for IE 10, support for Chrome 37 and 38 (beta) and also for Firefox 32 and 33 (beta).	Only support Windows system (added support for Windows 8)

(continued)



**Table 2** (continued)

Tool name/year/version released in that year	Understandability	Modifiability	Flexibility	Extendibility	Modularity	Cost-effectiveness	Reliability	Browser compatibility	OS compatibility
QTP/UFT 2012 Versions 11.5	Good and easy to learn	Being a commercial difficult to modify	Not so flexible	Not support much extendibility	Yes it has modular approach for development	Not freely available	It is reliable	Yes support multiple browser	Only support Windows system also added support for mobile testing
QTP/UFT 2011 Versions 11.0	Good looking result and enhanced results viewer	Costly to modify as it is a commercial tool	Yes it supports flexibility, but it is restricted as it is licensed	Difficult to extend	Yes it has modular approach for development	Not freely available	Yes it is reliable	Yes (record support for Firefox is now available)	No only support Windows system
Ranorex [11, 19, 20, 34]	It is an easy to use software for both people with or without programming knowledge	Difficult to modify Ranorex	Difficult to modify Ranorex	No, hard to extend Ranorex	Modularity is not fully supported	Costly	Yes, support reliability	Support multiple browser	No, its only Window OS

(continued)

**Table 2** (continued)

Tool name/year/version released in that year	Understandability	Modifiability	Flexibility	Extendibility	Modularity	Cost-effectiveness	Reliability	Browser compatibility	OS compatibility
Ranorex 2016 Versions 5.4.5 to 6.2.0	Upgrading of files, projects, and solutions has improved, creates a backup, and shows an upgrade report, view test report during test execution	Difficult to modify	It supports flexibility, but it is restricted as it is licensed	Functionality can be added but in limited manner	Modularity is not fully supported	Only trail version is free	It is reliable tool	Added support for android 7	Added support for iOS 10, added support up to Windows 10
Ranorex 2015 Versions 5.2.2 to 5.4.4	The report now signals modules with errors using an error icon	It supports modifiability but only by its original developer	Flexible up to some extent	Hard to extend because it is not open source	Modularity is not fully supported	Only trail version is free	Yes it supports reliability	Added support for Firefox 41 and higher and Android 6	Added support for Windows apps in Windows 100
Ranorex 2014 Versions 4.1.5 to 5.2.1	Improved facility for import and export functions	Costly to modify as it is a commercial tool	Not so flexible as it allows few update	Hard to extend	Modularity is not fully supported	Only trail version is free	Yes it is reliable tool	Added support for Firefox 34	Do not support all OS
Ranorex 2013 Versions 4.0.2 to 4.1.4	Image-based recording can now be enabled for mobile apps, improved report performance in Internet Explorer	Modifiability do not supported by users	It supports flexibility, but it is restricted as it is licensed	Hard to extend because it is a commercial tool	Modularity is not fully supported	Only trail version is free	Yes it is reliable tool	Added support for Firefox 26, Chrome 32, and newer versions of android also	Added object recognition support for Windows 8.1 preview apps

(continued)

**Table 2** (continued)

Tool name/year/version released in that year	Understandability	Modifiability	Flexibility	Extendibility	Modularity	Cost-effectiveness	Reliability	Browser compatibility	OS compatibility
Ranorex 2012 Versions 3.2.1 to 4.0.1	Added shortcuts for many features	Being a commercial difficult to modify	Not so flexible	Not support much extendibility	Modularity is not fully supported	Only trail version is free	Yes it is reliable tool	Added support for Firefox 18 and Android also	Not fully support all OS
Ranorex 2011 Versions 2.3.8 to 3.2.0	Improved usability for cut/copy/paste, report now provides links to corresponding recording items or user code	Costly to modify as it is a commercial tool	It supports flexibility, but it is restricted as it is licensed	Difficult to extend	Modularity is not fully supported	Only trail version is free	Yes it is reliable tool	Yes added support for Google Chrome and apple, safari and Firefox 8	Only Windows but added support for 64 bit
Test complete [11, 16, 18-20, 33]	Test steps are improved	Difficult to modify	Yes it supports flexibility	Functionality can be added	Modularity is not fully supported	Only trail version is free	Yes it is reliable tool	Support for Chrome, Internet Explorer, Firefox, Opera	Support for Windows, iOS
Test complete 2016 Version 11.0 to 11.31	Test steps are improved	Difficult to modify	Yes it supports flexibility, but it is restricted as it is licensed	Functionality can be added but in limited manner	Modularity is not fully supported	Only trail version is free	Yes it is reliable tool	Support for Chrome 49, Internet Explorer 11, Firefox 45, Opera 31	Support for Windows 10, added support for iOS 9.3

(continued)

Table 2 (continued)

Tool name/year/version released in that year	Understandability	Modifiability	Flexibility	Extendibility	Modularity	Cost-effectiveness	Reliability	Browser compatibility	OS compatibility
Test complete 2015 Version 10.0-10.60	Support for new technologies which improve its working	It supports modifiability but only by its original developer	Flexible up to some extent	Hard to extend because it is not open source	Modularity is not fully supported	(only trail version is free)	Yes it supports reliability	Support for Chrome 33 and Opera 19, Firefox 26	Support for iOS testing and Windows 8.1
Test complete 2014 Versions 9.0 to 9.31	Improved gui, enhanced report generation, test summary	Costly to modify as it is a commercial tool	Not so flexible as it allows few update	Hard to extend	Modularity is not fully supported	(only trail version is free)	Yes it is reliable tool	Not support all browser fully	Support for Windows 8 and Windows server 2012 support, support for Firefox 23 and Chrome 29
Test complete 2013 Versions 8.0 to 8.70	Support for various technologies like .net, visual studio	Modifiability do not supported by users	Yes it supports flexibility, but it is restricted as it is licensed	Hard to extend because it is a commercial tool	Modularity is not fully supported	(only trail version is free)	Yes it is reliable as it produces the desired result	Not support all browser fully	Support for Windows mobile 6 series, support for Firefox 6

(continued)

**Table 2** (continued)

Tool name/year/version released in that year	Understandability	Modifiability	Flexibility	Extendibility	Modularity	Cost-effectiveness	Reliability	Browser compatibility	OS compatibility
Test complete 2012 Version 7.0 to 7.52	The recording engine has been improved, quick search box for recording logs	Being a commercial difficult to modify	Not so flexible	Not support much extendibility	Modularity is not fully supported.	Only trail version is free	Yes it is reliable tool	Not support all browser fully	Now support Internet Explorer ver. 8, Windows 7. Now, you can run your tests under Microsoft Windows 7 support for Firefox 3.5
Test complete 2011 Version 6.0 to 6.52	Compress test results, performance has been improved	Costly to modify as it is a commercial tool	Yes it supports flexibility, but it is restricted as it is licensed	Difficult to extend	Modularity is not fully supported	Only trail version is free	Yes it is reliable as it produces the desired result	Not support all browser fully	Support for 64-bit applications

This makes them tedious to use for testing. In today's era, there is a requirement of such a tool which can be proved its capability to carry out the whole testing process in less time, costs less money, and needs less effort and man power. Also, during our study, we found few tools are widely used because of their features and performance, while some of them lag. So, in our further study, we give preference to such tools that are widely used.

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