Scalability and Performance of Selected Websites of Universities: An Analytical Study of Punjab (India)

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***Abstract*—Today, education has emerged as a major area of commercial activities. The access to various University websites through Internet has opened up new opportunities for the beneficiaries. The creation of these websites fully serves the purpose of educational institutions in advancing and achieving their goals. The varied information made available on these websites and the minimum transaction response time to address the queries of end-users can go a long way to influence their decision in selecting a particular course and an institution. The issue assumes greater significance especially in a developing country like India where a website development and deployment activity is primarily facing the shortage of formalized website design techniques and testing procedures. The performance of most of the University websites is reasonably well, but when accessed by only a few concurrent users. Thus, the aim of this study is to analyze and compare the scalability and performance of selected University websites of Punjab (India) by means of load testing. Simulation of realistic users' behavior is achieved through LoadRunner, a software tool for performance testing. Of all the University websites under study, on the basis of their scalability and performance, it has been found that the websites of Deemed and Central universities are the most and least efficient respectively. The findings of this study can be of great significance for the higher educational institutions in improving the performance quality of their websites resulting into their better ranking and satisfaction of the stakeholders. The paper also outlines the scope for further research in the area under study.**

Keywords*—Hits per second; scalability; performance; throughput; transaction response time; university websites

I. Introduction and Related Work

The advent of World Wide Web has greatly influenced every business in one way or the other. Frankly speaking, it has completely transformed our lives by providing access to a vast knowledge and information on every subject. Millions of Web applications serve billions of Web pages daily through software systems. Web applications have become interactive, dynamic and asynchronous through a number of revolutions [1], [2]. Web applications are an integral part of any website; and subsequently, existing websites have evolved from static information pages to dynamic and service-oriented applications. These are highly used for a broad range of activities on a daily basis in the health care, education, consumer business, banking and manufacturing sectors [3]. Academic institutions make their websites for a wide range of purposes which mainly include distribution of information to the public, delivering online learning facilities to students, promotion of their educational and research programmes and the like. Thus, through this medium, the universities are communicating with and disseminating information to various stakeholders. Students / prospective students, employees / prospective employees, parents, ranking organizations, and the media were identified as the regular users of academic websites [4]. If it is assumed that universities are the brands for education marketing, then websites emerge as a crucial part of this marketing process.

The website of an institution is a gateway to its information and services offered. As such, it should meet all the requirements of its stakeholders. A poor website of an organization can spoil its brand image, loose the potential customers, and weaken its organizational position. Thus, it is of utmost importance to explore those factors which highly influence the users' attitude towards a website which helps the organizations to chalk out a successful e-strategy for the purpose. Many research studies have established the relationship between Web quality factors and user acceptance [5]-[12]. This is due to the reason that Web quality factors can be controlled by an organization; and these can influence users' beliefs and their behavioral intention. A poorly performing website offering a product may fail in its objective. An effective website keeps a balance between end users' expectations and experience with the services being offered. Only those organizations can successfully achieve their goals which are able to lift end users' experience to a level that exceeds expectations. As the end users' expectations always keep on increasing, it is essential for organizations to improve their quality constantly. It raises the question: what should be improved to keep the end users satisfied? Lin [13] emphasized not only on the quality of information, but also the quality of system. System quality is technology-based and enables the users to get faster responses with more convenience and privacy [14]. The time to download a Web page is an important factor for most of the Internet users. The study undertaken by Hoffman and Novak [15] has established a positive correlation between website loading time and user satisfaction. Therefore, fast loading becomes essential for online transactions to be finalized. When loading time is below the expectations of users, they will either prefer to redirect the search engine to another site or give up their search [16]-[19]. Thus, it can be assumed that due to technology advances end users expect sites to be even quicker. The poor performance of a website may downgrade it in search engine results rankings.

Although a good number of websites exist in the academic domain today, yet only a small percentage of these websites satisfy their end users' requirements especially in developing countries like India. It has been observed that during the admission days, many of the University websites are not able to perform well on account of links opening slowly, some of the important links not opening at all, and lost payment transactions. However, such problems can be attributed to the limited use of formalized website design techniques, rapid advancement in Web technologies, limited experience and knowledge of individual designers and developers, short development and evaluation life cycle, lack of formalized website testing procedures, and less resource allocation for website design and development project [20]. Hite and Railsback [21], in their study, confirm that University websites have developed almost as rapidly as corporate websites. But a proper engineering approach for building a web system is not followed; and the engineering process itself is still to be engineered.

The whole scenario gives rise to the need for a thorough analysis of websites both during development and after deployment in order to ensure their conformance to high standards of quality especially in terms of performance. Website testing is considered from two distinct perspectives. The first perspective focuses on identifying the failures in functionality of a website, while the other perspective verifies the conformance of the site behavior with the specified non-functional requirements. The functionality of a website means what a system is supposed to do, while its non-functionality requirements means how a system is ought to be [22], [23]. The non-functional requirements of a system are often described as its "quality attributes". The non-functional requirements that a website is usually required to satisfy, either explicitly or implicitly, are shown in Figure 1.

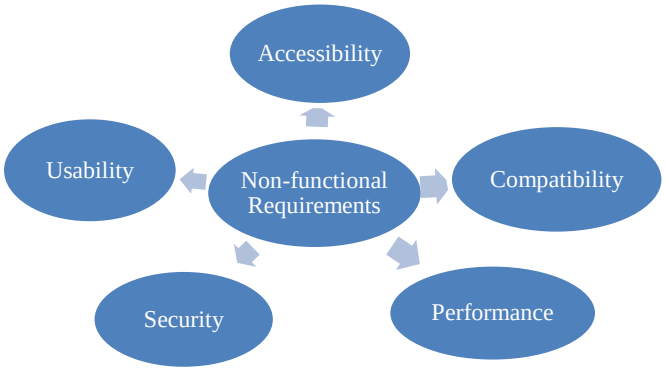


Fig. 1. Non-functional requirements of a website

Most of the methods and approaches followed to test the functional requirements of 'traditional' software can also be used for testing the websites. However, traditional testing theories and methods cannot be used as such to verify each non-functional requirement because of the peculiarities and complexities of websites. The Web application system is typically composed of a database (or the back-end) and Web pages (the front-end) with which users interact over a network through a browser. Garousi et al. [24] considered the website as a distributed system, with a client-server or multi-tier architecture. The other main characteristics are as follows:

- A wide number of users can access it concurrently.
- The use of different hardware, operating systems, Web browsers and network connections generates heterogeneous execution environments.
- A large variety of software components establish the heterogeneous nature of a system which it generally includes. These components can be constructed of different technologies / programming languages, for instance, Hypertext Markup Language (HTML), Cascading Style Sheets (CSS), JavaScript on the client-side and Hypertext Preprocessor (PHP), Ruby, Java on the server-side.
- The dynamic nature of a system makes the software components generate at run time as per user inputs and server status.

The characteristics as mentioned above pose a number of technical and non-technical challenges before the testers to effectively test the sites; and additional efforts are required in web testing [25]. Thus, specific testing activities need to be explored to test the non-functional requirements of a website.

Performance testing is a subset of performance engineering which strives to build performance into the implementation, design and architecture of a system. Liu [26] considers performance testing as a measure to find how fast an application can perform certain tasks, whereas scalability is used to measure performance trends over a period of time with increasing amounts of load. Performance testing consists of simulating multiple virtual users that send requests to the tested server concurrently for evaluating the application performance under a particular load. It is defined as the technical investigation carried out to identify the hurdles in a system, supports a performance tuning effort, determines compliance with performance goals & requirements, and/or collects other performance-related data enabling the stakeholders to make decisions related to the overall quality of the application/system being tested [27]. The performance of any system depends upon many parameters like response time, high throughput from the system, etc. [28]. In 2006, Google revealed that by reducing the size of web page "Google Maps" from 100KB to 80KB, their traffic shot up by 10% in the first week and then 25% in the following three weeks. The results produced by Amazon in 2007 were also the same. It was revealed that for every 100ms increase in load time of Amazon.com their sales decreased by 1% [29]. Thus, the performance of a website needs to be monitored regularly as it is an integral part of a Web design workflow and quality assurance programme.

Although website performance testing is of great significance, yet there has not been any significant study which examined the performance and scalability of University websites of Punjab (India). The higher education sector in the state of Punjab is highly vibrant, fast growing and highly competitive. This can be confirmed from the fact that 10 new universities have started their venture during the last five years.

Therefore, it is highly important for the universities not only to improve their academics and administrative procedures, but also the websites which is a common interface with their end users. Thus, the present study is the outcome of this research gap.

II. Research Objectives

The objectives of the study are as hereunder:

- To evaluate the scalability behavior of University websites by measuring how the average throughput and hits per second will increase with an increase in user load.
- To examine the performance of University websites by measuring average response time and the amount of data processed (throughput) for the same user load.

III. Research Methodology

The study focuses on certain selected websites of universities located in Punjab (India). Presently, there are twenty-five universities in Punjab which include central university (01), deemed universities (2), private universities (13), and state universities (09) (Appendix A). Therefore, stratified random sampling technique was applied to identify the University websites for the purpose of analysis. The university websites selected for this study are listed in Table 1.

TABLE. I. University Websites Considered for the Purpose of Analysis

University status	**University name**	**University web address**
Central Univ.	Central University of Punjab, Bathinda	http://www.cup.ac.in/
Deemed Univ.	Thapar University, Patiala	http://www.thapar.edu/
Private Univ.	Chandigarh University, Mohali	http://www.cuchd.in/
State Government Univ.	Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana	http://www.gadvasu.in/

University websites are analyzed through LoadRunner software, a tool for performance testing. It largely suits this research because the measurement of website performance parameters is, generally, beyond the scope of other techniques such as heuristic evaluation, user evaluation, etc. Also, the evaluations exercised by human users are, usually, based on qualitative criteria which can be prone to error. For performance testing, throughput and response time should be absolutely measured in a concrete and verifiable manner for a set number of users. The framework of evaluation procedure has been shown in Figure 2.

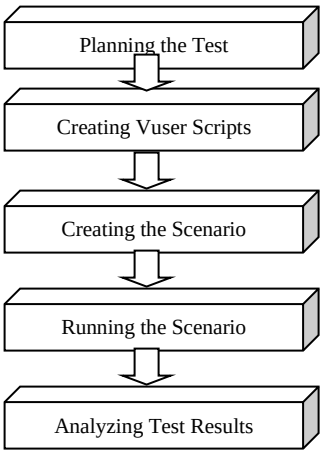


Fig. 2. Sequence of load testing activities performed

Planning the test was the first stage of experimental framework. After selecting the universities, the next step was to identify the web pages or links maximum explored by the end users. For this, a survey was conducted among the students who had recently taken admission in first year of the University programme. Their parents were also included in the survey. An enquiry was made from them to know which links were explored by them the most on the University websites at the time of seeking admission to various courses; and what sort of information they sought or expected under these links. The nine links identified for the purpose were "About Us", "Admissions", "Fee Structure", "Ph.D. / Research & Consultancy Cell", "Training & Placement Cell", "Hostel", "Downloads", "Contact Us" and "Scholarships / Fellowships / Financial aid". On the basis of these inputs, an attempt was made to find which pages/links of the University websites are suitable in the creation of script for performance testing. Uniform Resource Locator (URL) addresses for the identified pages/links of all the universities are listed in Table 2.

Further, scripts were created in Virtual User Generator (VuGen), a component of HP LoadRunner software. HP LoadRunner has 3 components, namely, Virtual User Generator (VuGen) which is used for script creation; Controller is used for executing the performance tests; and Analysis is used for analyzing the performance test results. The protocol used for script creation was Web (HTTP/HTML). The critical flows (Table 2) were first recorded for each university in a separate script file. The scripts were then optimized through parameterization, content checking, transaction naming and custom coding. The user inputs were handled through parameterization. The expected and actual response of the server request was matched through content checking. The transaction was considered passed only when there was a matching between the expected and actual response, otherwise, it was considered failed. Every user request was encapsulated within a transaction name. LoadRunner identified each

transaction through a name and reported its response time. Custom codes were added to determine the size of each visited web page. Scripting being a one-time activity, the same scripts were further reused for various test executions.

TABLE. II. URLS OF IDENTIFIED WEB PAGES

	Central University	Deemed University	Private University	State Government University
About Us	http://www.cup.ac.in/about_CUPB.php	http://www.thapar.edu/index.php/about-us/history	http://www.cuchd.in/about/	http://www.gadvasu.in/about-the-university.asp
Admissions	http://www.cup.ac.in/admission2016.php	http://www.thapar.edu/index.php/admissions/admissions-2016	http://www.cuchd.in/admissions/	http://gadvasu.in/noticedetails.asp?J=0&id=1449
Fee Structure	http://www.cup.ac.in/fee_structure.php	http://www.thapar.edu/images/fees/Fee%20Chart%20for%20ODD%20Semester%202016-17.pdf	http://www.cuchd.in/admissions/program-fee.php	http://www.gadvasu.in/matter.asp?MainCatID=2&SubCatID=70&ChildID=99&Catname=Detail+of+fees+for+UG+%26+PG+Programmes+under+College+of+Veterinary+Science
Ph.D. / Research & Consultancy Cell	http://www.cup.ac.in/research_initiatives_n.php	http://www.thapar.edu/index.php/admissions/phd-programme	http://www.cuchd.in/research/	http://www.gadvasu.in/matter.asp?MainCatID=3&SubCatID=17&Catname=List+of+Ongoing+Research+Projects
Training & Placement Cell	http://www.cup.ac.in/placement_cell.php	http://www.thapar.edu/index.php/students/placements/introduction	http://www.cuchd.in/placements/	http://www.gadvasu.in/PlacementCell.asp?Cat_ID=6
Hostel	http://www.cup.ac.in/campus_life.php	http://www.thapar.edu/index.php/students/hostels	http://www.cuchd.in/student-services/hostel-facility.php	http://www.gadvasu.in/matter.asp?MainCatID=6&SubCatID=35&Catname=Hostels+
Downloads	http://www.cup.ac.in/student_forms.php	http://www.thapar.edu/index.php/forms	http://www.cuchd.in/downloads/	http://www.gadvasu.in/downloads.asp
Contact Us	http://www.cup.ac.in/contact.php	http://www.thapar.edu/index.php/campus/contact-us	http://www.cuchd.in/contact/	http://www.gndu.ac.in/gndu2014/contact.asp
Scholarships / Fellowships / Financial aid	http://www.cup.ac.in/scholarships.php	http://www.thapar.edu/index.php/scholarships	http://www.cuchd.in/scholarship/	http://www.gadvasu.in/matter.asp?MainCatID=2&SubCatID=71&Catname=Awards+and+Medals

Once the script was created for each university, scenarios were created in Controller. A scenario is a file that defines the scripts to execute, the number of virtual users executing those scripts, and the machine that will host (load generators) the virtual users. Virtual users are not real users. Each virtual user works according to its script taken up for execution. For each University, scenario was created for 15, 30 and 45 users load test. Each scenario had a ramp-up phase (starting Vusers) during which the users were added gradually to the application till its predetermined limit was reached. After ramp-up, the script was executed for a fixed time span. During this period, users kept on doing their activities continuously. Later, during

the ramp-down phase, users started leaving the application gradually. The properties set for these actions in a particular scenario are depicted as below in Table 3.

TABLE. III. SCENARIOS SETTINGS

Load Tests (Concurrent User Load)	Action	Properties	Ramp-Up Phase Time	Approx. Ramp-Down Phase Start Time
15 Users	Start Vusers	Start all Vusers: 1 every 00:00:15 (HH:MM:SS)	Initial 3 min 30 sec	After 1 hr 3 min 30 sec
	Duration	Run for 01:00:00 (HH:MM:SS)		
	Stop Vusers	Stop all Vusers: 2 every 00:00:15 (HH:MM:SS)		
30 Users	Start Vusers	Start all Vusers: 1 every 00:00:15 (HH:MM:SS)	Initial 7 min 15 sec	After 1 hr 7 min 15 sec
	Duration	Run for 01:00:00 (HH:MM:SS)		
	Stop Vusers	Stop all Vusers: 2 every 00:00:15 (HH:MM:SS)		
45 Users	Start Vusers	Start all Vusers: 1 every 00:00:15 (HH:MM:SS)	Initial 11 min	After 1 hr 11 min
	Duration	Run for 01:00:00 (HH:MM:SS)		
	Stop Vusers	Stop all Vusers: 2 every 00:00:15 (HH:MM:SS)		

All the scenarios were executed after their creation; and the test results were taken up for analysis under the third component of HP LoadRunner software, namely, Analysis

IV. FINDINGS AND DISCUSSIONS

A. Scalability comparison of selected University websites

Scalability is a performance testing parameter that helps us to identify if an application (website) is capable of scaling with increase in number of concurrent users. Various attributes of an application can be used to gauge its scalability like response time, transactions per second, etc. However, the best possible ways to determine the scalability of any application are throughput and hits per second. Throughput is a performance testing metric which helps us to determine the amount of data (in bytes) an application is able to process. Typically, it is expressed as bytes/sec. Hits per second is a performance testing metric which helps us to determine the number of hits made on the Web server by users during each second of the load test [30]. The scaling of various websites with respect to throughput parameter with varying user loads is expressed through Table 4 and Figures 3 to 6.

TABLE. IV. THROUGHPUT STATISTICS REPRESENTING THE SCALABILITY BEHAVIOR OF UNIVERSITY WEBSITES

University Status (I)	Concurrent User Load (II)	Average Throughput (Bytes per second) (III)	Total (Bytes) (IV)	%age Increase in	
				User Load over previous run (V)	*Average Throughput over previous run* (VI)
Central University	15 Users	292,797.660	1,266,349,881	NA	NA
	30 Users	525,114.716	2,485,893,065	100	79.344
	45 Users	547,154.627	2,720,452,806	50	4.197
Deemed University	15 Users	292,949.293	1,315,635,274	NA	NA
	30 Users	565,405.674	2,663,060,724	100	93.005
	45 Users	839,690.288	4,224,481,841	50	48.511
Private University	15 Users	193,694.812	853,225,645	NA	NA
	30 Users	370,743.814	1,750,281,548	100	91.406
	45 Users	528,576.357	2,721,111,086	50	42.572
State Government University	15 Users	149,146.676	650,279,506	NA	NA
	30 Users	279,409.866	1,343,682,047	100	87.339
	45 Users	400,076.013	2,025,584,854	50	43.186

Table 4, column III determines the average throughput received; while column IV highlights the total data received from the web server during the entire test duration. Average throughput is calculated as total throughput divided by total test duration (in sec). Column V determines by what percentage the user load has increased as compared to previous runs. When user load is raised from 15 to 30, it shows 100% increase; and the increase is 50% when raised from 30 to 45. Column VI displays the percentage increase in average

throughput from the previous run. NA (not applicable) indicates that the current test has been taken as a baseline test.

It can be observed from the throughput graphs given below that for all the universities across various load tests, throughput has increased with the ramping up of users in ramp-up phase. The ramp-up phase period is constituted of initial 3 minutes 30 seconds, 7 minutes 15 seconds, and 11 minutes for the 15, 30 and 45 users' load test respectively. It was noticed during the ramp-down phase that the throughput decreased as the users came out of the application gradually; and finally, reached to zero. The ramp-down phase start time was 1 hour 3 minutes 30 seconds, 1 hour 7 minutes 15 seconds, and 1 hour 11 minutes for the 15, 30 and 45 users' load test respectively.

Figure 3 clearly depicts that with the increase in user load from 15 to 30 **(**100% rise) in the case of Central University of Punjab the throughput also increased by 79.344% (Table 4), though not proportionally. Later on, the user load was further increased from 30 to 45 users, but the throughput managed to increase by 4.197% only (Table 4). For this test, the throughput was neither stable, nor it showed any increase with the increase in user load (during a span of 12 to 35 minutes). Also, the throughput managed to become stable, but it does not scale up proportionally (during a span of 36 to 72 minutes). This indicates that the site under investigation faces the problem of scalability.

The curves shown in Fig. 4 represent the throughput achieved by Thapar University (a deemed University) for all the three tests. It shows that once the users' load stabilized, the throughput also got stabilized with ignorable fluctuations during a span of 15 to 65 minutes. With an increase in user load, the throughput also increased proportionally. With increase in user load from 15 to 30 (i.e., 100% rise) and 30 to 45 (i.e., 50% rise), the throughput increased by 93.005% and 48.511% respectively (Table 4), which evidently indicates that the website is scalable.

Fig. 5 highlights the throughput achieved by Chandigarh University (a private University) for all the three tests. It shows that once the users' load got stabilized, the throughput also got stabilized with least fluctuation for 15 and 30 users test during a span of 15 to 65 minutes which was not observed for 45 users test. In the case of this University, when user load was increased from 15 to 30 (i.e., 100% rise), the throughput also increased proportionately, i.e., 91.406%. However, when the test was conducted for 45 users the throughput was highly unstable; and it showed an increase of only 42.572% (Table 4). It indicates that the site under investigation faces the problem of scalability.

The throughput achieved by Guru Angad Dev Veterinary and Animal Sciences University (a state government University) under all the three tests is highlighted in Figure 6. The results showed that there was 87.339% increase in the throughput after raising the user load from 15 to 30 (Table 4). Thus, the proportional increase in throughput was considerably less than that of user load. Also, when the user load was increased from 30 to 45, the throughput with the increase of 43.186% was stable, but not proportional. Thus, the results indicate the University site under study needs to focus on certain scalability issues.

Hits per second determine the number of hits made on the web server by the users during the load test. Table 5 carries the data showing hits per second for all the University websites under study. The columns III and IV represent the number of hits per second and total hits received respectively by the web server during the entire test duration. It was observed that 100% increase in user load resulted into a maximum increase of 92.693% hits per second in the case of Thapar University (a deemed University), while it was the least, i.e., 79.016% in Central University of Punjab. However, when the user load was increased by 50%, the hits per second showed a maximum increase of 48.893% in the case of Thapar University, while it was as low as 1.367% in Central University of Punjab. Similar results were found after a comparison was made between the data provided in column VI of Tables 4 and 5.

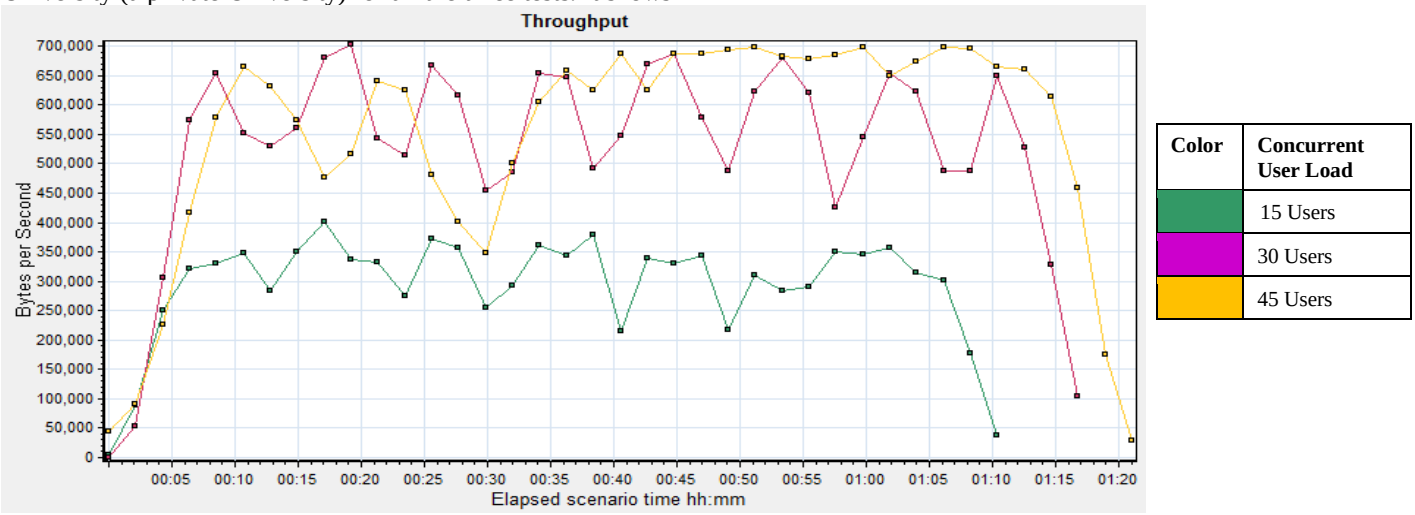
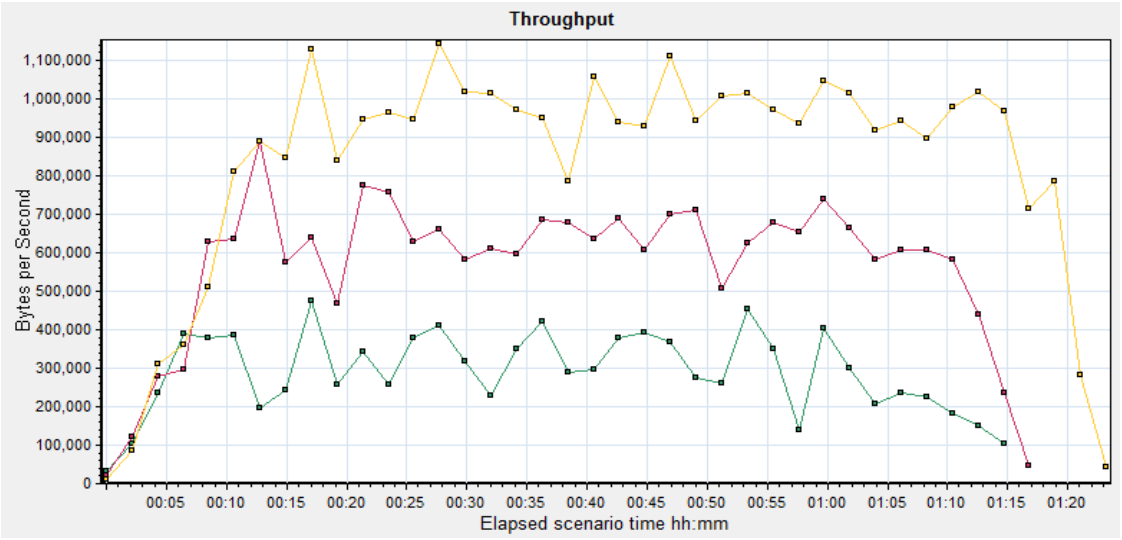
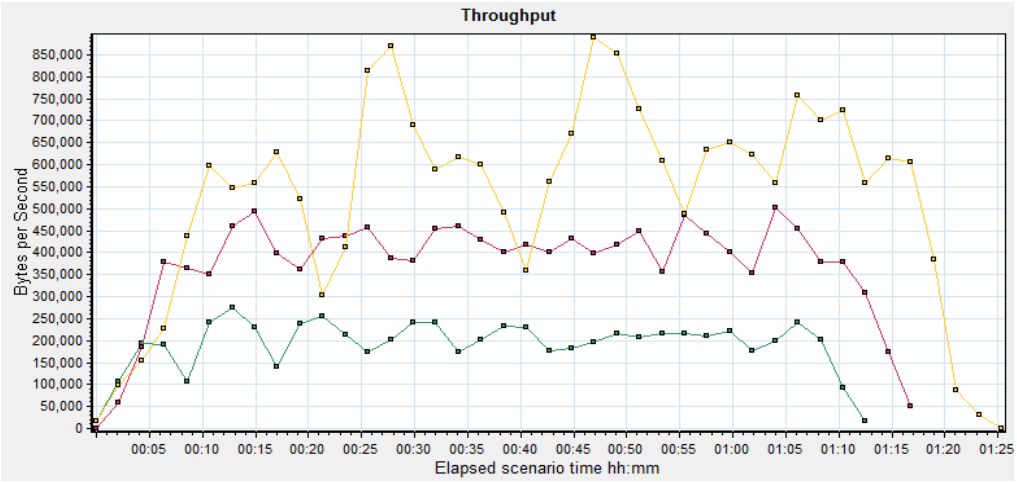


Fig. 3. Throughput behavior of Central University for 15, 30 and 45 users' load



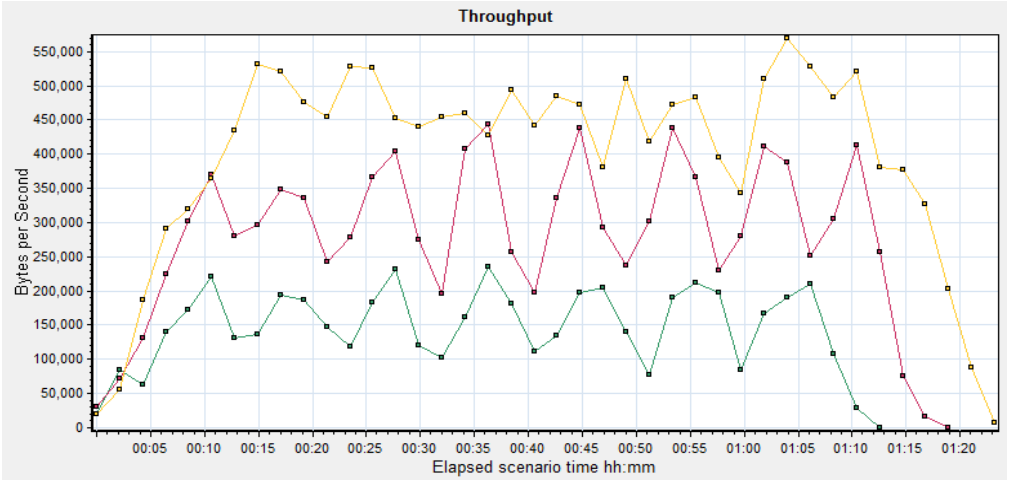
Color	Concurrent User Load
	15 Users
	30 Users
	45 Users

Fig. 4. Throughput behavior of Deemed University for 15, 30 and 45 users' load



Color	Concurrent User Load
	15 Users
	30 Users
	45 Users

Fig. 5. Throughput behavior of Private University for 15, 30 and 45 users' load



Color	Concurrent User Load
	15 Users
	30 Users
	45 Users

Fig. 6. Throughput behavior of State Government University for 15, 30 and 45 users' load

TABLE. V. HITS PER SECOND STATISTICS REPRESENTING THE SCALABILITY BEHAVIOUR OF UNIVERSITY WEBSITES

University Status (I)	Concurrent User Load (II)	Average (Hits per second) (III)	Total (Hits) (IV)	% Increase in	
				User Load over previous run (V)	*Average Hits per second over previous run* (VI)
Central University	15 Users	3.474	15,025	NA	NA
	30 Users	6.219	29,439	100	79.016
	45 Users	6.304	31,343	50	1.367
Deemed University	15 Users	8.622	38,723	NA	NA
	30 Users	16.614	78,251	100	92.693
	45 Users	24.737	124,453	50	48.893
Private University	15 Users	14.233	62,698	NA	NA
	30 Users	27.273	128,758	100	91.618
	45 Users	38.855	200,027	50	42.467
State Government University	15 Users	11.309	49,309	NA	NA
	30 Users	21.234	102,112	100	87.762
	45 Users	30.437	154,102	50	43.341

On the basis of results pertaining to throughput (Table 4) and hits per second (Table 5), it can be said that of all the four universities under study, the websites of Thapar University and Central University of Punjab are the most and least scalable respectively.

B. Performance comparison of selected university websites

The performance of University websites under study has been evaluated on the basis of time taken (response time) and data processed (throughput) for the same user load.

Transaction response time is the basic performance testing metric which helps us to determine the time taken by an application to process the user request. By definition, it is the time duration between users sending the request and receiving its complete response from the server, expressed in seconds. Tables 6 to 9 contain the data showing the transaction response time for all the universities across various user loads. Here, column I demonstrates all the links of the website that a virtual user hits in its iterations while running the script. Column II exhibits the user load for which the test was executed. Columns III to V display the minimum, average and maximum response time taken by that transaction for the respective user load. Column VI determines the number of times an expected response was received for that transaction. Similarly, column VII explains the number of times an expected response failed in its transaction. Most of the transactions failed due to step download timeout error. The error of step download timeout occurs when the user does not receive the whole response in a stipulated time as mentioned in load runner scripts. In this study, tests have a fixed value of 300 seconds. Column VIII demonstrates the page size of the respective link.

The data shown in Table 6 clearly reflects that the web page "Fee Structure" has taken the highest "average transaction response time" for all test runs, i.e., 10.754, 30.856 and 71.281 seconds for 15, 30 and 45 users load test respectively. The page size is of 4.337 MB which makes it the heaviest of this website. In the "Fee structure" page, a PDF file having all the fee details of various courses offered by the university has been downloaded from the server. The web page taking the least "average transaction response time" is not consistent across the different load tests, i.e., 1.423 secs by "Contact Us" page (15 users test), 4.176 secs by "Downloads" page (30 users test) and 10.247 secs by "Training & Placement Cell" page (45 users test). The page having the smallest size of 0.254 MB is "Downloads" for this university. It has been observed that the failure rate for the transactions is as high as 11.7% of the passed transactions for 45 users test run.

A glance at Table 7 provides that the web page "Hostel" has taken the highest "average transaction response time" for all the test runs, i.e., 12.132, 13.609 and 15.856 seconds for 15, 30 and 45 users load test respectively. The page size is of 6.988 MB which makes it the heaviest of this website. Hence, the average response time taken for a transaction is also the highest. However, the web page "Fee Structure" has shown the least "average transaction response time". The average transaction response time recorded after a load test of 15, 30 and 45 users is 1.618, 1.806 and 2.576 seconds respectively. Further, this page is of the smallest size, i.e., 0.326 MB.

As per the results shown in Table 8, in the case of Chandigarh University, the web page "Training & Placement Cell" is the heaviest of this website with a size of 1.241 MB. Thus, the "average transaction response time" is also the highest, i.e., 10.688, 11.075 and 27.731 seconds for all the test runs conducted under a load test of 15, 30 and 45 users respectively. However, the web page "Download" is the smallest with a size of 0.459 MB. Thus, the "average transaction response time" is also the minimum, i.e., 1.991, 2.041 and 7.884 seconds for a similar load test of 15, 30 and 45 users respectively.

TABLE. VI. TRANSACTION RESPONSE TIME STATISTICS OF CENTRAL UNIVERSITY OF PUNJAB FOR ALL LOAD TESTS

Transaction Name (I)	Load Tests (II)	Minimum Transaction Response Time (sec) (III)	Average Transaction Response Time (sec) (IV)	Maximum Transaction Response Time (sec) (V)	No. of Passed Transactions (VI)	No. of Failed Transactions (VII)	Page Size in MB (VIII)
About Us	15 Users	0.893	2.039	11.238	108	1	0.427
	30 Users	0.886	4.932	48.297	226	5	
	45 Users	0.958	13.122	125.254	292	37	
Admissions	15 Users	0.883	1.986	12.410	107	1	0.267
	30 Users	0.903	4.505	36.533	219	7	
	45 Users	0.926	11.211	125.043	269	23	
Fee Structure	15 Users	7.010	10.754	35.375	106	1	4.337
	30 Users	6.931	30.856	122.511	212	7	
	45 Users	7.212	71.281	227.626	244	25	
Ph.D. / Research & Consultancy Cell	15 Users	0.955	1.715	8.646	106	0	0.402
	30 Users	0.973	6.161	122.918	203	9	
	45 Users	1.012	12.316	135.353	215	29	
Training & Placement Cell	15 Users	0.855	1.625	10.340	105	1	0.258
	30 Users	0.886	4.657	122.75	199	4	
	45 Users	0.878	10.247	72.995	199	16	
Hostel	15 Users	6.851	10.124	21.974	104	1	4.233
	30 Users	7.047	29.566	95.418	195	4	
	45 Users	7.003	62.559	232.129	157	42	
Downloads	15 Users	0.868	3.275	122.009	102	2	0.254
	30 Users	0.878	4.176	37.404	190	5	
	45 Users	0.911	10.640	45.244	148	9	
Contact Us	15 Users	0.839	1.423	8.589	100	2	0.255
	30 Users	0.884	4.707	124.029	185	5	
	45 Users	0.926	10.423	69.498	136	12	
Scholarships / Fellowships / Financial aid	15 Users	1.824	7.204	122.849	98	2	1.019
	30 Users	1.830	8.816	48.033	176	9	
	45 Users	1.859	19.439	62.044	120	16	

TABLE. VII. TRANSACTION RESPONSE TIME STATISTICS OF THAPAR UNIVERSITY FOR ALL LOAD TESTS

Transaction Name (I)	Load Tests (II)	Minimum Transaction Response Time (sec) (III)	Average Transaction Response Time (sec) (IV)	Maximum Transaction Response Time (sec) (V)	No. of Passed Transactions (VI)	No. of Failed Transactions (VII)	Page Size in MB (VIII)
About Us	15 Users	2.476	6.292	140.435	108	3	0.570
	30 Users	1.133	4.469	11.817	225	3	
	45 Users	2.586	5.832	17.238	352	8	
Admissions	15 Users	2.833	8.980	213.856	108	0	0.890
	30 Users	2.636	5.442	22.659	222	3	
	45 Users	2.815	7.321	25.129	344	8	
Fee Structure	15 Users	0.597	1.618	4.589	107	1	0.326
	30 Users	0.618	1.806	13.783	220	2	
	45 Users	0.579	2.576	11.894	343	1	
Ph.D. / Research & Consultancy Cell	15 Users	3.210	6.859	128.859	107	0	0.890
	30 Users	2.886	5.479	16.560	220	0	
	45 Users	2.872	6.888	23.299	343	0	
Training & Placement Cell	15 Users	2.856	4.680	23.021	106	1	0.538
	30 Users	2.387	4.470	18.067	215	5	
	45 Users	2.497	5.620	15.592	340	3	
Hostel	15 Users	8.510	12.132	29.697	106	0	6.988
	30 Users	7.214	13.609	31.892	207	8	
	45 Users	7.929	15.856	36.673	338	2	
Downloads	15 Users	2.504	6.281	225.255	106	0	0.530
	30 Users	2.480	5.175	182.622	205	2	
	45 Users	2.347	5.376	18.389	332	6	
Contact Us	15 Users	3.339	10.648	80.455	102	4	0.533
	30 Users	3.077	9.555	22.391	203	2	
	45 Users	3.140	10.723	20.166	329	3	
Scholarships / Fellowships / Financial aid	15 Users	2.798	4.462	13.579	102	0	0.535
	30 Users	2.512	4.650	22.926	200	3	
	45 Users	2.458	5.596	14.367	326	3	

TABLE. VIII. TRANSACTION RESPONSE TIME STATISTICS OF CHANDIGARH UNIVERSITY FOR ALL LOAD TESTS

Transaction Name (I)	Load Tests (II)	Minimum Transaction Response Time (sec) (III)	Average Transaction Response Time (sec) (IV)	Maximum Transaction Response Time (sec) (V)	No. of Passed Transactions (VI)	No. of Failed Transactions (VII)	Page Size in MB (VIII)
About Us	15 Users	1.875	2.319	4.861	112	0	0.508
	30 Users	1.912	2.457	30.732	230	0	
	45 Users	1.979	10.851	75.738	358	0	
Admissions	15 Users	3.026	5.325	30.457	112	0	0.767
	30 Users	3.011	4.913	30.956	230	0	
	45 Users	3.266	15.537	109.318	358	0	
Fee Structure	15 Users	3.348	4.951	31.335	112	0	0.919
	30 Users	3.353	4.669	33.155	230	0	
	45 Users	3.590	16.848	97.816	358	0	
Ph.D. / Research & Consultancy Cell	15 Users	2.234	3.040	30.383	112	0	0.529
	30 Users	2.170	2.890	30.326	230	0	
	45 Users	2.185	10.519	81.621	358	0	
Training & Placement Cell	15 Users	8.871	10.688	37.424	112	0	1.241
	30 Users	8.688	11.075	38.762	230	0	
	45 Users	8.946	27.731	136.325	357	1	
Hostel	15 Users	2.101	2.733	30.293	112	0	0.601
	30 Users	2.078	3.066	31.579	230	0	
	45 Users	2.183	10.231	84.570	357	0	
Downloads	15 Users	1.643	1.991	3.044	112	0	0.459
	30 Users	1.591	2.041	9.726	230	0	
	45 Users	1.687	7.884	66.541	357	0	
Contact Us	15 Users	3.219	4.476	31.049	112	0	0.792
	30 Users	3.202	4.284	34.371	230	0	
	45 Users	3.248	14.321	93.436	357	0	
Scholarships / Fellowships / Financial aid	15 Users	3.510	4.847	30.380	112	0	0.843
	30 Users	3.508	4.452	31.449	230	0	
	45 Users	3.543	15.305	112.491	357	0	

It is clear from Table 9 that in the case of Guru Angad Dev Veterinary and Animal Sciences University, the web page "Fee Structure" is the heaviest of this website with a size of 1.461 MB. Thus, the "average transaction response time" is also the highest for all the test runs, i.e., 6.440, 7.440 and 17.403 seconds for 15, 30 and 45 users load test respectively. Of all the web pages, the best "average transaction response time" for the web page "Training & Placement Cell" is 3.203, 3.716 and 8.039 seconds for 15, 30 and 45 users load test respectively. Further, the web page "Hostel" is of the smallest size, i.e., 0.492 MB.

While analyzing the results of all the University websites under study, it has been found that more the size of web page, higher would be the response time and vice versa. The composition of each web page, i.e., the type of files it integrates has also been analyzed. However, the composition of only those web pages having a size of over one MB in the case of all the University websites is shown in Table 10.

TABLE. IX. TRANSACTION RESPONSE TIME STATISTICS OF GURU ANGAD DEV VETERINARY AND ANIMAL SCIENCES UNIVERSITY FOR ALL LOAD TESTS

Transaction Name (I)	Load Tests (II)	Minimum Transaction Response Time (sec) (III)	Average Transaction Response Time (sec) (IV)	Maximum Transaction Response Time (sec) (V)	No. of Passed Transactions (VI)	No. of Failed Transactions (VII)	Page Size in MB (VIII)
About Us	15 Users	4.327	5.126	40.642	111	0	0.576
	30 Users	4.585	5.256	22.074	232	0	
	45 Users	4.574	11.354	57.102	350	6	
Admissions	15 Users	3.132	3.347	4.554	111	0	0.590
	30 Users	3.389	3.893	8.342	231	1	
	45 Users	3.333	9.959	80.649	350	0	
Fee Structure	15 Users	5.944	6.440	12.886	111	0	1.461
	30 Users	6.308	7.440	21.295	228	3	
	45 Users	6.222	17.403	104.814	343	7	
Ph.D. / Research & Consultancy Cell	15 Users	2.931	3.383	23.521	110	1	0.516
	30 Users	3.228	3.750	8.216	220	8	
	45 Users	3.239	8.403	55.385	338	5	
Training & Placement Cell	15 Users	2.891	3.203	18.317	109	1	0.496
	30 Users	3.189	3.716	5.583	217	3	
	45 Users	3.211	8.039	56.334	333	5	
Hostel	15 Users	2.893	3.208	19.856	107	2	0.492
	30 Users	3.225	3.755	5.203	213	4	
	45 Users	3.187	8.482	96.564	324	9	
Downloads	15 Users	3.168	3.637	20.711	105	2	0.540
	30 Users	3.408	3.942	5.682	210	3	
	45 Users	3.274	8.455	54.565	317	7	
Contact Us	15 Users	3.095	3.477	23.416	105	0	0.506
	30 Users	3.286	3.878	5.249	209	1	
	45 Users	3.285	9.384	62.160	304	13	
Scholarships / Fellowships / Financial aid	15 Users	2.919	3.400	22.784	103	2	0.498
	30 Users	3.254	3.870	20.018	203	6	

TABLE. X. CONTENT BREAKDOWN OF WEB PAGES (IN KB) OF SIZE AT LEAST ONE MB FOR ALL THE UNIVERSITY WEBSITES

University Status	Webpage Name	Images			CSS	Java Script	PHP	PDF	Others*
		JPG	PNG	GIF					
Central University	Fee Structure	131.047	0	10.389	16.552	71.456	26.614	4181.482	3.131
	Hostel	4195.42	0	10.389	16.552	71.456	37.752	0	3.151
	Scholarships / Fellowships / Financial aid	131.047	0	10.389	16.552	71.456	27.742	783.222	3.042
Deemed University	Hostel	247.689	6723.082	0	48.11	115.543	0	0	20.891
Private University	Training & Placement Cell	637.162	267.011	6.03	34.314	310.484	0	0	15.285
State Government University	Fee Structure	1272.369	60.806	8.095	25.462	67.542	0	0	62.147

* Validation scripts, fonts, URLs, directory overheads, etc

Table 10 reveals that University sites under study have used various types of images like PNG, JPEG and GIF. Images constitute 97.420% of page size for the web page "Hostel" of the Deemed University website (having URL: *http://www.thapar.edu/index.php/students/hostels*) which adversely affects the transaction response time. Similarly, in the case of Central University website (having URL: *http://www.cup.ac.in/campus_life.php*), images for the web page "Hostel" constitute 97.026% of the overall page size which lead to increase the transaction response time. Further, the website of Deemed University has mainly used PNG images which are heavier in size as compared to other types of images such as JPG and GIF used by other universities for their websites. However, in the case of Central University website, no PNG image has been used.

Table 11 demonstrates the data explaining average response time with respect to all user load tests undertaken for all the four selected University websites. The average response time has been calculated by taking mean of "average transaction response times". The results, also presented graphically in Figure 7, explain the performance of all the University websites more clearly and effectively. Finally, the overall average response time results calculated for each university across all load tests are presented at the bottom of this table.

A good website is always capable of having a stable response time and maximum throughput under different user load tests. Here, Central University's website has the highest overall average response time of 13.324 seconds across all user load tests (Table 11). As is evident from Fig. 7, there is a great variation in the average response time of selected University websites under different user load tests. This variation is the highest in the case of Central University's website. Thus, it can be said that the website of this University is the least performing among the four University websites. Further, although the overall average response time for the State University website is 6.098 seconds which is less than that of Deemed University (6.755 seconds), yet the throughput is comparatively more than double in the case of Deemed University under all the load tests (see Table 11). Furthermore, Deemed University's website has shown the most stable average response time under different user loads. Thus, it can be said that Deemed University's website is the best performing site of all the four selected University websites.

V. CONCLUSIONS

The main conclusions drawn from this research work are as follows:

- From the scalability point of view, the website of Deemed University under study has been found to be the best as an increase in user load has resulted into an increase in the throughput and hits per second both in tandem and proportionally. Whereas the Central University's website is the least scalable among the sites studied in this research as there has not been a proportional increase in throughput and hits per second against the user load.
- As far as the performance of all the University websites under study is concerned, in terms of overall average response time along with the amount of data processed and stability of average response time relative to varying user load tests, the websites of Deemed and Central universities have been found to be the most and least performing sites respectively.

All the considered Universities have their own underlying hardware, server configurations and technology architecture for their websites. Therefore their performance testing results are bound to be different despite the fact that all the other test parameters such as test users, test scenarios, internet speed etc. are the same for all of these Universities. However each of the universities has a common goal of serving to all the stakeholders' viz. the existing & aspirant students, the faculty members and providing them a good user experience. Hence, this study is an attempt to highlight which university website is designed for providing better performance and scalability

relatively and suggests how other Universities may perform better.

C. Recommendations

The recommendations made on the basis of findings of this study are as follows:

- Larger the size of a web page, higher would be the value of average transaction response time. Thus, the average transaction response time can be improved by way of optimizing the size of web page.
- The size of images to be posted on a website should be reduced to the minimum without data loss and compromising on image' visual quality.
- Web page developers should use file compression utility, e.g., GZIP to minimize the amount of data being downloaded by the end users. It would lead to improve the "average transaction response time".

TABLE. XI. PERFORMANCE STATISTICS OF ALL UNIVERSITY WEBSITES

Load Tests (I)	University Status (II)	Average Response Time (sec) (III)	Total Throughput (Bytes) (IV)
15 Users	Central University	4.460	1,266,349,881
	Deemed University	6.883	1,315,635,274
	Private University	4.485	853,225,645
	State Government University	3.913	650,279,506
30 Users	Central University	10.930	2,485,893,065
	Deemed University	6.072	2,663,060,724
	Private University	4.427	1,750,281,548
	State Government University	4.388	1,343,682,047
45 Users	Central University	24.582	2,720,452,806
	Deemed University	7.309	4,224,481,841
	Private University	14.358	2,721,111,086
	State Government University	9.992	2,025,584,854
Overall average response time of Central University across all the load tests			Average of (4.460, 10.930, 24.582) = 13.324 sec
Overall average response time of Deemed University across all the load tests			Average of (6.883, 6.072, 7.309) = 6.755 sec
Overall average response time of Private University across all the load tests			Average of (4.485, 4.427, 14.358) = 7.757 sec
Overall average response time of State University across all the load tests			Average of (3.913, 4.388, 9.992) = 6.098 sec

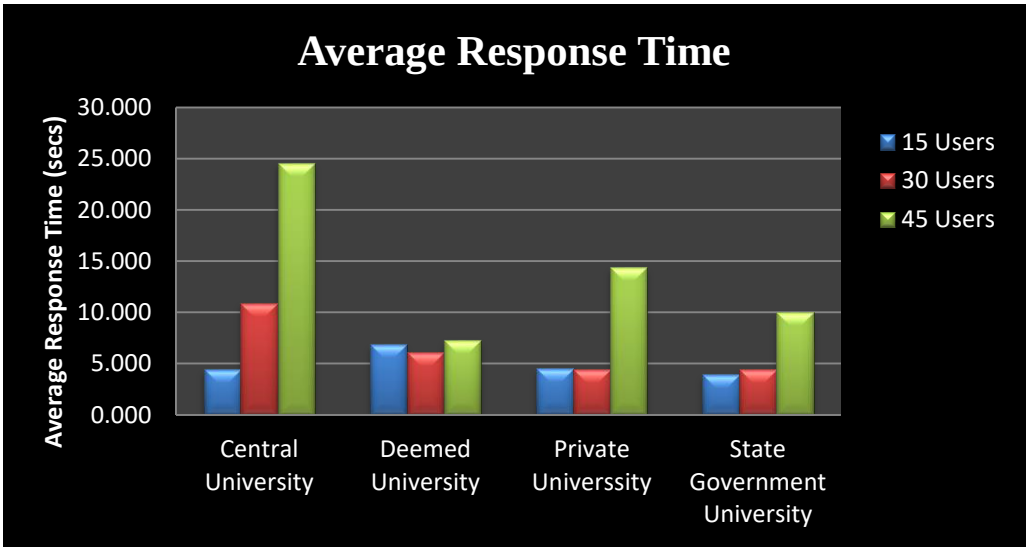


Fig. 7. Average response time of selected University websites under different load tests

D. Scope for further research

- The present study is confined to the websites of selected universities located in the state of Punjab (India) only. However, to corroborate and extend the outcomes of this study, an extensive research is required to be carried out with a larger sample of universities covering diverse regions of the country and world as well.
- The dynamic nature of websites suggests that a longitudinal approach can be followed to examine the changes in performance level of university websites.

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APPENDIX A. LIST OF UNIVERSITIES IN PUNJAB (INDIA)

TABLE. XII. CATEGORIZATION OF UNIVERSITIES ACCORDING TO THEIR STATUS

University status	University name	University web address	Total number of universities
Central	Central University of Punjab	http://www.cup.ac.in/	01
Deemed	Sant Longowal Institute of Engineering and Technology	http://sliet.ac.in/	02
	Thapar University	http://www.thapar.edu/	
Private	Adesh University	http://adeshuniversity.ac.in/	13
	Akal University	http://auts.ac.in/	
	Chandigarh University	http://www.cuchd.in/	
	Chitkara University	http://www.chitkara.edu.in/	
	DAV University	http://www.davuniversity.org/	
	Desh Bhagat University	http://www.deshbhagatuniversity.in/	
	GNA University	http://gnauniversity.edu.in/	
	Guru Kashi University	http://www.gurukashiuniversity.in/#/	
	Lovely Professional University	http://www.lpu.in/	
	Rayat-Bahra University	http://www.rayatbahrauniversity.edu.in/	
	RIMT University	http://www.rimt.ac.in/	
	Sant Baba Bhag Singh University	http://www.sbbsuniversity.in/	
	Sri Guru Granth Sahib World University	http://sggswu.edu.in/	
State Government	Baba Farid University of Health Sciences	http://bfuhs.ac.in/	09
	Guru Angad Dev Veterinary and Animal Sciences University	http://www.gadvasu.in/	
	Guru Nanak Dev University	http://www.gndu.ac.in/	
	Guru Ravidas Ayurved University	http://www.graupunjab.org/	
	I. K. Gujral Punjab Technical University	https://www.ptu.ac.in/	
	Maharaja Ranjit Singh State Technical University	http://www.mrsstu.ac.in/	
	Punjab Agricultural University	http://web.pau.edu/	
	Punjabi University	http://www.punjabiuniversity.ac.in/	
	Rajiv Gandhi National University of Law	https://www.rgnul.ac.in/	

Source: University Grants Commission's website (http://www.ugc.ac.in/, 12/05/2016)