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A LEAP TOWARD OPTIMIZATION: SHOULD TEST CENTERS AT EDUCATIONAL INSTITUTIONS BE CENTRALIZED OR SHOULD THEY REMAIN DECENTRALIZED?

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***Abstract**: In this paper, we introduce a formal approach to customizing test centers for educational institutions. The paper formulates a mathematical method to reveal the size of a test center according to the number of students in the institution under consideration and the number of registered classes. To address the problem presented in this paper we analyzed some existing test centers using the distributed system approach and compared them to the proposed centralized test centers. We compared the two prototypes intellectually, economically, and operationally. The concluding mathematical formula would easily help any educational institution to optimize their spending efficiency and in advance without compromising the test quality.*

***Keywords** Centralized systems, decentralized systems, computer-based testing, educational institutions*

I. INTRODUCTION

Centralized and distributed systems have been investigated by researchers in many fields. Our investigation is directed toward distributed and centralized test centers. In this paper we aim to find out whether test centers at educational institutions should be centralized or remain decentralized. We investigated the problem economically, operationally, and intellectually. Then we compared our proposed model with an existing one drew conclusions accordingly.

Our hypothesis asserts that the centralized system should outperform the distributed system economically and operationally. The intellectual impacts are beyond the scope of this paper; however, we have provided some literature which addresses this intellectual problem. We claim that a solution to the problem addressed in section 1.1 is feasible, with high efficiency and accuracy, when implementing our proposed prototype discussed in section 3, without harming testing quality.

We claim that there is a feasible solution which strongly supports our hypothesis regarding the centralization of test centers. Extensive research was carried out and more than a hundred papers were carefully investigated. We investigated papers which compare computer-based tests (CBTs) with paper-and-pencil tests (PPTs). Advantages and disadvantages of centralized and decentralized centers were explored. Other systems such as personalized systems, peer to peer (P2P) systems, and codified systems were investigated in relation to test centers' efficacy. The paper explores the impacts of each system on the regulation and management of students' tests at educational institutions. We developed a mathematical formula which can be used for any educational institute to find the size of the test center for a particular institute. Several experimental examples have been provided to demonstrate the efficiency of the formula and its economical advantages. The paper highly recommends the implementation of e-testing and shows the amount of manpower wasted in the existing systems. This research provides a solution to the shortage of faculty members and shows how we can employ computer technology in one of the most appropriate ways to address this scarcity.

The rest of the paper is organized as follow. Section 2 reviews previous work, some of which advocates our claim. Section 3 describes our method and its similarities with some existing methods. In section 4, we present the results. Finally, we conclude the paper in section 5 with suggestions for future works.

1.1 The problem

The problem encountered in some institutions is whether to test students using computers or to test them using traditional pen and paper methods. This is not the real problem addressed in this paper; we address a more controversial issue. The overall problem addressed in this paper is whether to centralize distributed test centers in schools, colleges, universities and educational institution or whether they should remain decentralized. To investigate the problem we chose some existing test centers and analyzed them carefully; we then modified these centers as necessary. Comparing the existing distributed test centers example with a proposed centralized one would indicate the solution.

II. BACKGROUND

The need to differentiate between centralized and decentralized system has been widely addressed by previous literature. Researchers in knowledge management (KM), system engineering, and business administration published their works favoring the centralized system over the decentralized, or the opposite, according to a specific problem. However, the trend shows an inclination toward centralized systems over decentralized ones. In business, Eric Berkman [1] proved that companies are centralizing their systems due to cost effectiveness. Berkman does not favor the distributed system, saying that it reinvents the wheel for each business unit. However, the author emphasized proper implementation, as improper implementation may lead to business crisis. For its organizational and business advantages, Berkman prefers the centralized system as it improves staff and organizational personal retention and leads to clear job descriptions which help with reaching organization goals.

In their book [2], Harsen and others analyzed the system carefully from the KM point of view and proposed their suggestions for a codification approach, "centralized systems", and a personalization approach, "decentralized systems". The authors concluded that a codification system would provide high quality, reliability, and fast implementation when reusing the codified knowledge. The KM property which is considered as an advantage by the authors is the development of a large codified document system, which supports our proposed method. The authors also showed that connecting people with the reusable codified knowledge is an Information Technology (IT) property of codification. These properties support our hypothesis in favor of centralizing test centers at educational and business organizations. Yiman and Kobsa [3] studied the centralization and decentralization issues in internet-based KM systems (KMSs). The authors showed that centralized systems might be better than decentralized ones in exploiting, manipulating, and monitoring an organization’s resources. However, the authors emphasized having a backup mechanism for such systems to restore the system in case of failure. Accorsi and Costa [4] compared centralized systems with P2P systems and showed the advantages of both. The authors concluded that centralized systems showed significant evolution in terms of functionalities. According to Maier [5], centralized KMSs provide powerful tools to consolidate knowledge. However, the authors emphasized on having advanced machines, optimization and large effort to search in the existing database. In their paper [6], Yang and Ho reported that centralized KMSs create a large and homogenous organizational memory (OM). In the OM the knowledge is incorporated, collected, represented, and organized uniformly. The authors concluded that centralization has advantages over other systems architecture in terms of scope, control, and organization. In their paper [7], Susarla and others presented some deleterious problems regarding P2P architecture. They looked at it from the management’s point of view. The authors reported that it is very hard to monitor P2P systems knowledge quality, which is a serious demerit of the system, and that this is an important issue concerning the test centers, which could help in eliminating all sorts of problems and disadvantages in this regard. The authors furthermore reported that the organization of information is hard to manage under consistent methods. They mentioned that security and overload of data are, in addition, serious system problems. Parameswaran and others [8] reported that distribution of content may undermine the quality of information searches. Thorn [9] studied the use of KM in education and investigated educational information systems (EIS). The author presented three major issues regarding EIS. He emphasized the target group and desired outcome and also suggested that managing data is another key factor in EIS.

Finally, what kind of metrics is to be used to assess students? Wall [10] asserted that a centralized approach for information systems in an organization is more efficient and controlled and much better as regards efficiency and economy. Robson [11] concluded that a centralized information system is effective in gaining or regaining control over an organization's information system. This is also advocated by Kroenke and Hatch [12] as the authors reported that centralized systems provide better control over other systems. Robenson [11] reported that a centralized system might be much slower than other systems. However, our system in Section 3 shows a better system budget using a centralized approach. Ahituv and others [30] concluded that a centralized system provides higher efficiency due to a reduction of duplication, more standardization, and control, as well as utilization. Dosouza and others [13] investigated KMSs in non-collected environments and compared centralized systems to non centralized systems. The authors reported that codified systems have the advantage of amalgamation as well as cohesiveness and availability to all members of the organization. The authors related client/server architecture to codified systems and distributed systems to P2P systems or personalized systems. The authors provided another advantage of storing knowledge in a centralized domain, which is that it could have multiple dimensions and categories, thus facilitating the filtering and categorizing mechanism. As the authors reported, knowing where the knowledge resides infers knowing the location and accessing privileges and tools. On the other hand, the authors mentioned that a disadvantage of storing some of the knowledge might be that it may be unrelated to some of the organization members.

In a report provided by Prometric [14], Meissner studied the successful conversion steps toward computer-based (CB) testing. In his study, the author reported that several months might be required to complete the system conversion. He showed no obstacles to conducting this conversion; however, its difficulty may vary according to the system size and complexity. Several companies including Prometric specialize in providing technical support as well as hardware or software. The author reported that CBTs are much less expensive compared to PPTs in the long run. The author provided solutions to some problems, such as: the size of the exam item bank, security, exam scoring, benefit to examinees and sponsors. He presented some recommended conversion processes. In his discussion on the benefits of CBT, the author identified the following: flexibility, advanced item types, data-richness, test results, security, consistency, reliability, availability of immediate scoring, streamlined logistics, and engaging navigation and presentation.

Rich evaluated some computer-based testing models and systems in his study [15]. He provided some useful cost benefit criteria for such an evaluation. The author reported that implementation of computer-based testing would almost certainly be associated with cost increases in item bank design, research and development (R&D) expenditures, and item production cost. However, we assert that, in the long run, the system will be economically competitive, as presented in Sections 3 and 4.

There are many studies in psychometrics in this field, published by Sand and others [16], Hambleton [18], Parashal and others [19], Folk and Smith [20], Jodon and others [21], Luecht [22] [23] and [24], and Linden and others [25]. Multiple fixed tests were studied by Parshall and others [19]; the authors showed that each test could be generated simultaneously and automatically. They reported that each test will have the same set of statistical and content specifications. Computer-adaptive testing (CAT) was studied by Lord [26] [27] and Kiugsbury and others [28]. The authors showed the precision of CAT in test length, level of measurement precision, and approach to competency. Other models were presented by Hetter and Syspson [29], Stocking and Ying [32], Lewis and Sheehan [33], Wainer and Keily [34] and Luech and Nurgester [17]. Evaluation of testing methods was studied by Mills and Stocking [35]. Machuso and others [36] studied the computerization of the American Midwifery Certification Board (AMCB) examination. The authors discussed the candidates' convenience in computer-based testing and reported that the exams are more often available and more sites exist. Reporting of results and scores is immediate, which is another advantage. The author concluded that the candidate cost of the exam is much less than the paper test as it has more sites and time, which requires less travel and less absence from work and budgetary outlay.

The advantage of improved security when using compute-based exams is considered as one of the benefits to candidates. Rosem [37] agreed with this paper regarding advanced security in CBT. Butler [38] studied students' attitude and behavior toward CBTs. The author suggested that a lot of benefits would be available to students, such as offering scored and small CBTs outside classroom time. Robertson and Ober [39] reported that large class size has a negative impact on students. This was also advocated by Lindsay and Patonsaltzberg [40]. Butler's [38] findings regarding having more exams while not sacrificing classroom time is recommended by many others, for example Kika and others [43], Pikunas and Mazzota [44], and Turney [45]. Neuman and Beydoun [46] and Bugbee [47] reported that students would present the same performance if the CBT is similar in format to the PPT. Barua [48] concluded that the development of hardware and software influenced the CBT, with advantages in multimedia and speech which cannot be found in regular tests. The same result was reported by Zakrzewsk and Bull [49]. These advantages make CBTs more efficient, economical, and practical, and this result was also advocated by Bennett [50].

In their report, Professional Testing Inc. [51], discussed the important issues when converting to CBTs. They discussed issues such a CBT resources, items banks, delivery methods, scheduling, software, sites, security, selecting vendors, stakeholders, and feasibility analysis. The company reported many advantages to the examinees and fewer disadvantages, such as the requirements demanded by particular programs. Basu and others [52] discussed the employment of multimedia adaptive CBTs. Other researchers supported Basu, such as Allen [53], Gonzalez and others [54], Parlangeli and others [56], Yau and Joy [57], Volery and Lord [58], and Zenisky and Sireci [41]. Multimedia had already been used in education, as reported by Feng and others [59], Galvao and others [60], Lee and others [61], Mitchel and Savill-Smith [62], and Patomaki and others [63]. Base and others [52] reviewed some examples of multimedia for students' tests. Lim and others [64] compared CBTs to PPTs and found that 80% of students preferred CBT over PPT. Bodmann and Robinson [65] investigated the performance differences between CBTs and PPTs. The authors reported that CBT has advantages of time and flexibility and that there was no difference in scoring, regardless of the level of flexibility. Inouye and Bunderson [66] showed that CBT can be standardized and a sequence of items can easily be manipulated. Bugbec and Bernt [67] showed the scheduling flexibility of the CBT. As shown in [66], Olsen and others [68] showed that CBT can collect metrics such as test items and latency which cannot be collected by PPTs. Russell [69] reported that students with lower keyboard and computer skills performed worse on CBTs, which is consider to be a disadvantage when compared to PPTs. However, computer skills are improving among students nowadays worldwide. Clariana and Wallace [70] found that gender, competitiveness, and computer familiarity were unrelated to the test modes. Dimock [71] found that students may take longer the first time on CBTs, but not on subsequent CBTs. Bartlett and others [72] investigated deeper issues; they studied and compared online testing with traditional testing and found that traditional testing took a longer time. However, the scoring results were correlated between both methods. The authors reported several advantages for both students and instructors. Online testing with secure access was investigated and recommended by many researchers such as Bocij and Greasley [73], Bull [74], Daly [75], Doughty and others [76], Hazari [77], Greenberg [78], Gibson and others [79], Kumar [55], Treadway [42] and [41], and Zakrzewski and Bull [31].

III. METHOD

We consider CBTs to be one of the most brilliant and brave implementations by the College of Technology at Makkah (CTM). In this paper, we show our implementation as an example and we compare its advantages and disadvantages to those of PPTs. We compare the economical and operational aspects of the two models. However, the comparison of intellectual aspects has been addressed by other literature and mentioned earlier in this paper. One of the most important advantages of using CBTs is the standardization of scoring which was reported by our predecessors, as was observed in the implementation by CTM. Receipt of a prompt result is another advantage, as is accurate scoring. After explaining the comparison between CBTs and PPTs, we will recommended our model for deployment in similar colleges and show its scalability for larger institutions such as universities. Our statistics in the CTM project show that we have 282 invigilator teams each consisting of two invigilators. In addition, 5% of the manpower would be on duty as a backup support team in case of absence and emergencies. We also have 141 technical support personnel with scheduled tasks supervising the exam to provide technical assistance if needed. 12 labs were used, consisting of 240 computers. To ensure full operation, the computer center and e-training center were on duty to resolve any issues or difficulties. The examination times start between 8:00 am and 3:00 pm, or seven hours per day, and last for two weeks or ten business days. Therefore we have:

7 hours * 10 days = 70 hours

The number of exams open for students is as follows:

282 invigilator teams * 20 students per lab = 5660 exams

Each exam has an exam period of 2 hours + break of 30 minutes, so the total exam time is:

5660 * 2.5= 14,150 hours

Our observation shows that 85-95% of the students finish their exams in 10-20 minutes. In another words, we can assume that at least 85% of the students finish in 20 minutes, so we would have 85% of the labs' time free after only 20 out of a possible 150 minutes; or, we can rephrase our findings to: 85% of the labs using only 20/150 or 13% of the possible time, which means that, theoretically, we can save up to 87% of our expenditure when we wisely operate the exam system.
Our expense can be calculated as follows:

manpower of 282 teams * 2 + 141 supervisory individuals + two departments (computer center, e-learning center) + other administrative personnel

Adding to this the huge power consumption for at least 87% unnecessary time, we would be pouring quite a lot of resources down the drain unwisely.

Let us do more precise calculations. The exam time is 2.5 hours, or 150 minutes for the first and second exam periods and 120 minutes for the third exam period. We have 282 teams, and assuming that we divide the 282 teams between the three exam periods giving 94 teams for each period, we would have:

94 teams * 2.5 + 94 teams * 2.5 + 94 teams * 2 = 94 * (2.5+2.5+2) = 658 hours

658 hours * 20 students = 13,160 exam hours

If we use a centralized CBT and, according to our records and observation we allocate 0.5 hours for each student per exam (which is more than the worst case scenario (20 minutes)), the total time needed is:

282 teams * 0.5 hours * 20 students = 2820 exam hours.

If we want to finish the exams in one week, and if we want to work 8 hours a day, then:

8 hours per day * 5 business days = 40 hours per week

$$\frac{\text{2820 exam hours}}{\text{40 hours per week}} = \text{70.50 exam hours at a time}$$

If we have 20 computers in each lab, then we need:

$$\frac{70.5}{20} = 3.525 \text{ labs} \approx \text{only 4 labs}$$

According to this quick calculation and without any optimization to the exam monitoring policy, we would be using only:

$$\frac{2820}{13160} = 21.43\ \%$$

and we would save 78.57% of our expenditure. As we are not implementing this method so far in most institutions, we are wasting at least 78.57% of our resources. Further improvement will be analyzed in the following sections.

If we have 4 labs operating for 8 hours a day, then the exam will finish in one week. How many invigilators do we really need?

If we want to implement fully centralized computer controlled test centers, then we need only two to three monitoring individuals and a few administrative personnel. However, if the organization prefers to use the regular monitoring system, we need:

$$4 \text{ labs} * 8 \text{ hours} = 32 \text{ hours}$$

If each invigilator is on duty for 2 hours, we would have:

$$\frac{32}{2} = 16 \text{ persons per day or } 16 * 5 = 80 \text{ people}$$

We need only two operators (each would work from 8 am to 4 pm) and only one technician in case of emergency

IV. RESULTS, SCALABILITY AND MATHEMATICAL MODEL

Our model can be scaled to suite any educational institution for the k-12 system, college, or university levels. Regardless of the number of exams and subjects, or the complexity and diversity of the exams, our proposed model will suit them all according to the following mathematical formula.

Assume that the exam time (e) is recommended to be 2 hours and operation efficiency (λ) is recommended to be 25% of the exam for all students and the total time needed (T). The efficiency factor is used to find the average using the total exam time. For instance, if the total exam time is 2 hours and $\lambda = 0.25$, then the occupied time is 30 minutes. If (N) is the number of exams, then:

$$T = \lambda \,.\, N \,.\, e$$

The number of exam days needed (D_n) is found according to the following:

$$D_n = \frac{T}{h} \text{ days}$$

where (h) is the working hours per day and is recommended to be 8 hours. To find the minimum number of days (D_m) needed for all students in the organization to finish the exam, we need to relate it to the dependent variable (C_t), which is the number of computers available:

$$C_t = \frac{Dn}{Dm}$$

If we have 2820 exam hours and if the working hours is 8 hours a day, we will need:

$$D_n = \frac{2820}{8} = 352.5 \text{ days}$$

If we want to finish all exams in one week or 5 business days then:

Number of computer needed = $\frac{352.5}{5}$ = 70.5 computers.

Then, the number of labs (L) is:

$$L = \frac{\text{number of computer needed (Cn)}}{\text{number of computer in each lab (Cl)}}$$

$$L = \frac{70.5}{20} \approx 4$$

The model is therefore:

$$L = \frac{Ct}{Cl}$$

$$C_t = \frac{Dn}{Dm}$$

$$L = \frac{Dn}{Dm} \cdot \frac{1}{Cl}$$

$$= \frac{Dn}{Dm*Cl}$$

$$D_n = \frac{T}{h}$$

$$L = \frac{T}{h*Dm*Cl} = \frac{\lambda . N . e}{h . Dm . Cl}$$

In our example we use the following values:

λ = 25%, N = 282 * 20 = 5640 , e = 2 hours , h = 8 , D_m = 5 , C_l = 20

$$L = \frac{0.25*2*5640}{8*5*20} = 3.525 \approx 4 \text{ labs of 20 computers each}$$

Now try yours - you will be amazed!

Another example: suppose a university has 20,000 enrolled students where each student has an average of five classes. We want to find the size of the test center.

If h = 8 , λ = 25%, e = 2 , D_m = 5 , C_l = 20, N = 20,000 * 5 = 100,000

$$L = \frac{0.25*2*100{,}000}{8*5*20} = 62.5 \text{ labs} \approx 63 \text{ labs}$$

However, if we tune the value of D_m to 12 days and h = 10 hours and C_l to 30 computers, we will need only 13.8 or 14 labs to test all 20,000 students in all their classes (on average, five classes per student). The operation cost of 14 labs would be much less than operating the whole university for two weeks with a lot of professors and staff members.

V. Conclusion

This paper proposed a down to earth implementation of testing centers with sufficient scientific support. Economical aspects were discussed clearly with examples and a mathematical model was introduced to suit all dependent variables that might be found in any educational institution. A recommendation for further investigation is proposed and real implementations would reflect the power of centralized systems in CBTs.

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