Geographic Information Systems based performance assessment: Case study of selected medical libraries in Iran

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ABSTRACT

The study aims at determining the capability of Geographic Information Systems (GIS) in mapping library performance indicators. Six categories were identified as the potential library performance indicators in the study: per capita space, per capita seat, per capita staff, collection flow, circulation per capita, and per capita costs of providing printed sources. A comprehensive checklist was designed for data collection. The collected data were analysed utilizing ArcGIS version 10.7. Correlations between the six identified library performance indicators were validated in the study. ArcGIS software has the capability to display performance indicators in the form of clear images to conduct suitable analysis. Displaying performance indicators in the form of graphs and tables without using GIS makes data analysis and presentation difficult and it lacks precision and generalization. Maps incorporating performance indicator analysis using GIS, function as blueprints for displaying information on maps. The study validates the capability of GIS in mapping library performance indicators.

Keywords: Geographic Information System; Performance evaluation; Performance indicators; Academic libraries

INTRODUCTION

Academic libraries have played a significant role in the campus-wide organization and accessibility to geographical collections serving departments (Larsgaard 1998). Technological developments in recent years have brought changes in managing library facilities, including in-library use and occupancy of library study space. Geographic Information Systems (GIS) is one area of technology that has significantly impacted libraries of all types due to the high demand of spatial information by the users, as it "allows users to take information, view that information spatially and analyse that information; therefore, users can recognize patterns, see correlations and reach conclusions" (Elliott 2014, p.8). GIS is utilized across many disciplines for multiple purposes,

and is considered to be better than other systems in incorporating spatial data analysis into visual presentation which can be easily deployed and is relatively economical (Xia 2004a).

From historians to marketers, the power of analysing data spatially is being used in various fields, such as in making informed decisions regarding best transportation routes for hazardous materials (Zografos and Androutsopoulos 2008); discovering possible geographical influences on tactical decisions in battlefield (Horwitz 2012), or plotting a new site for a business (Wood and Browne 2007). GIS has been used in combination with qualitative methods in several participatory studies (Dennis et al. 2009; Townley et al. 2016). A fine example is where community members describe their experience with asthma in controlling their asthma symptoms through photos and narratives which are geographically referenced (Keddem et al. 2015). Studies on the use of GIS as a tool to measure and analyze libraries services in libraries are very few. Kim (2018) designed a delivery routing system using GIS for a public library system to display delivery route`s road network using ArcGIS. The study provided a shortest route connecting all the libraries for information delivery and resource sharing. Another study conducted by Shen (2018) proposed library space information model (LSIM) where spatial information and book attribute information was integrated to visually show bookshelf location in an academic library. Pinto and Ochoa (2019) highlighted the need of performance assessment of libraries in light of United Nations (UN) 2030 sustainable development goals. However, no single study exists on the capability of GIS for library performance assessment.

The objective of the current study is to assess the capability of GIS in performance assessment of academic libraries, which are generally qualitative in nature. Performance evaluation is an indispensable element for non-profit organizations such as libraries in decision making and fund provisioning where significant amount of government funds is involved. Timely evaluation of the quality of service is vital for performance evaluation to determine the drawback and inefficiencies at work (Bavakutty and Majeed 2005; Omidifar and Moosavizade 2009). Moreover, considering the objectives of higher education today university library systems are bestowed with onerous responsibilities which makes their evaluation inevitable, moving towards more outcome-based assessment instead of relying merely on input, output, or resource metrics. The commonly practiced performance evaluation techniques in libraries are such as accreditation, benchmarking, total quality management, ISO standards, and performance indicators using library service quality instruments such as ServQual, and LibQual. This study is an attempt to determine the potential capabilities of GIS in performance assessment of libraries.

RELATED LITERATURE

GIS technology has high potentiality and flexibility which could be useful in many ways as compared with traditional means of performance measurement such as excel and SPSS (Pournaghi and Pournaghi 2010). Liu et al. (2016) confirm that GIS research was significantly correlated with the development of personal computers, and there was a statistically significant quadratic polynomial growth in GIS-related articles. Recently, GIS have been very intensively applied in social life and in public health in particular (Murad and Tomov 2012). Despite the valuable applications of GIS in performance measurement, it has remained a relatively neglected approach for researchers in the library and information science (LIS) discipline. Limited studies have been carried out in this area. Data analysis in previous LIS studies have been often conducted using traditional statistical

software packages in the form of tables, charts and graphs. Bishop and Mandel (2010) who explored library literature that uses GIS in practice and research highlighted the practical implication of the tool that could benefit library services by (a) generating maps to convey more information than tables and text alone, and (b) allowing spatial analysis of library services inside the library and in a library's service areas. It is expected that using GIS, visualization of performance indicators will expose the capability to measure and compare library services effectively.

A few studies on GIS applications in libraries are well-documented. LaRue (2004) carried a study of GIS in public libraries in Chicago to deterimine if the technology could be used to improve collection development of consumer health materials. In this study, ArcView GIS program maps were developed to display public libraries and demographic information, so that the librarians while seeing the maps were able to check the items during the library acquisition process easily. The study showed that GIS can assist in defining the exact make-up of the population that a library serves, and recommended that purchase decisions be justified with hard data from ArcGIS. Kong, Fosmire and Branch (2017) showed how GIS service plays an important in academic libraries' effort to support digital humanities and social science. The researchers suggested that "a library's GIS service can support humanities and social science from the research collaboration, learning support, and outreach perspectives, with different focuses according to the stages of learning and research" (Kong, Fosmire and Branch 2017, p. 413). In a recent study, Zhang and Liu (2019) used spatial point pattern analysis in GIS to understand the temporal patterns of library visiting activities of university students in Chengdu City, China, using a four-week smart card dataset. The study showed that GIS methods can reveal a lot of information on the temporal pattern of library activities.

In an attempt to examine the possibility of library space management through the GIS maps, Xia (2005c) carried a study to explore the capability of GIS to visualize the occupancy of reading room spaces in academic libraries. Users of the academic libraries too have problem to find the specific source due to lack of familiarity with shelves classification and structure of the large collections in different parts. As such, in another study, Xia (2005b) showed how GIS could present the source positioning capability in libraries by integrating the GIS source positioning system and Online Public Access Catalog (OPAC) that made library users see their search results in both text and image format and are guided to the exact position of the source. Ou, Pan and Huang (2017) proposed a library intelligent document navigation system based on GIS, using RFID, ArcGIS and Sharp Map technology. The GIS-based system is able to locate the specific collection information of the literature to each layer of the bookshelf and display the information of the library. The researchers described that the application of the system in the library can further improve the library document management and information service efficiency, as well as strengthen the library information service function, and the library information security centre status.

Studies also showed that GIS was used to better understand potential library users and improve library service planning. Hertel and Sprague (2007) applied GIS as a library planning tool to analyse census data in order to identify potential library users, and then maps were prepared for each census data to display demographic data of potential users at a radius of three miles from two libraries. The study did not only present demographic data about potential library users both visually and quantitatively, but also determined how far from these libraries the new one should be built, and the convenient place to build it. Brundin (2007) used ArcGIS to investigate if there were any spatial patterns and regional differences in six library performance measures (general information, staff,

collections, service transactions, and expenditures) for 303 Ontario public libraries which provided the base to correct budget priorities in libraries and improve their collections and services. Brundin concluded that "using a GIS to analyze and visualize public library performance measures is an effective way of clarifying certain data patterns, as it is much easier to discern patterns on a map than it is in either tabular or graphical format" (Brundin 2007, p.9).

While other countries have found its way into the application of GIS-based technology in libraries for many years, such studies in Iran are quite new. In a recent study, Pournaghi (2017) applied GIS in collection management, covering systematic weeding, collection development and document selection. Using ArcGIS, a spatial database of the Central Library of Tehran University was created. The study justified the potential of GIS in improving the status of managing the library ources and contributing to make weeding more systematic and supplying the sources. In an earlier study, Pournaghi et al. (2013) proposed a model of mapping library collection through GIS and implemented it in mapping library collection at the shelf level. The study showed that if library users search a given source in created spatial database, they could see the item location in the library floor map at floor, section, and shelf levels Such database helps users to find the exact location of the source and saves them time improving the accessibility of the sources.

METHOD

The study used a descriptive research approach involving central and academic libraries affiliated to the Tehran University of Medical Sciences (TUMS) and Shahid Beheshti University of Medical Sciences (SBUMS). Census method of sampling, involving all members of the population, was used. All 22 libraries became the samples, where eleven of them are affiliated to TUMS and the remaining eleven are from SBUMS (see Appendix A).

A total of ten GIS-based indicators, out of the 40 validated performance indicators used to better assess library service quality in Poll and Boekhorst (2007) (see Appendix B), were used and visually represented in the study. Each indicator is defined as follows:
(a) "Per capita space": the net space per person of library users.
(b) "Per capita seat" : the provided seat per person to library users for studying.
(c) "Percentage of seats occupied": the average of percentage of seats occupied in the library over the year.
(d) "Opening hours and demand": comparison of the working hours, start and end time of the library with users demand.
(e) "Expenditure on information provision per capita": the information provision expenditure per person of library users.
(f) "Per capita staff": full time employees per person of library users.
(g) "Percentage of stock not used": the percentage of loaning resources that have not been used over the year.
(h) "Ratio of acquisitions costs to staff costs": the acquisitions costs divided by the costs on regular staff.
(i) "Acquisition speed": the average order date of a document and its delivery from the vendor.
(j) "Media processing speed": the average number of days between the date a media arrives at the library and the date it is available for use.

Data collection involved a survey questionnaire which was designed based on the performance indicators. The survey was personally administered to the librarians or library directors. All 22 libraries responded to and completed the questionnaire. Data were analysed using ArcGIS version 10.7 and data analysis involved the following four stages:

a) Conceptual model development and data modelling

Since selecting an optimal measure as an effective factor on geometric accuracy and variation of features is one of the important parameter affecting quality, therefore the urban basic maps 1 : 160000 were applied as optimal measure. Data modelling is one of the most basic steps of creating a GIS because GIS data model enables the computer to represent the real geographical elements as graphical elements, and data modelling means determining the geospatial data item and descriptive information related to geospatial data. At this stage, geospatial features, non-spatial features (e.g. an object, location, phenomenon or any other concepts that the data related to them are collected but they could not be displayed in respective measure) and required descriptive items were determined. In geographic dictionary, the word “feature” means a real-world object on map. In other words, “feature” is the smallest level of the map information item (ArcGIS 2019; Horwitz 2012; Sadeghnejad 2016).

b) Work procedures and techniques

At this stage, the required and appropriate data including the descriptive and geospatial data are collected. Descriptive data are data which represent the features characteristics and specifications contained in this study, covering all data related to the studied libraries performance indicators and some other descriptive data such as the university and college name gathered through the questionnaire. In this study, feature is defined as a display of each library on the map. Descriptive data of every feature (library) were entered in an attribute table created by ArcGIS version 10.7. Geospatial data is defined as data which display the correlation between geographical features on the earth's surface that include basic urban map 1 : 160000 and geographical coordinates of each libraries by using Google Earth software.

c) Data management and analysis

A layer for each library was created through the Arc Catalog application program (one of the ArcGIS program), then every layer was entered in ArcMap (another ArcGIS program). At this stage, attribute tables were made for every respective layer. To enter the value into attribute tables, a feature must be made for each layer. To create a feature, the X and Y points of every library obtained from Google Earth were entered in the attribute table, then the respective feature was found on Tehran map that previously added by ArcMap. By creating the feature, the respective value for each attribute, i.e. the performance indicators, were entered in the respective attribute tables. Thus, 22 layers were created in ArcMap for the entire libraries under study.

d) Receive output in thematic maps format

The layers of all libraries of TUMS and SBMS including a layer of the entire libraries of both the universities were created, using the capability of merge in ArcMap. The purpose of merging the libraries was to put together performance indicators for both the university libraries for comparative analysis. While analysing the indicators, the values were manually entered into the software with reasonable procedure and by using the software classification/manual capability to maintain the integration of values in both university libraries. Then, symbols were used according to indicators to display them on map, and finally the output of respective images was received.

FINDINGS

The libraries sampled in this study are displayed on their geospatial position in all images taken from ArcGIS software version 10.7. The libraries of TUMS and SBUMS have been marked in red and blue respectively. For data representation, abbreviations have been used, such as (A) paramedical, (C) central, (D) dentistry (F) nutrition, (H) health, (M) medical, (Mg) medical management and information, (N) nursing and midwifery, (P) pharmacy, (R) rehabilitation, (S) health, safety and environment, (T) new medical technologies, and (TM) traditional medicine colleges. The points of some libraries overlap with each other due to the proximity of the peculiarities, so these points were highlighted and displayed in single coloured frames next to the map in order to differentiate them from each other. Determining the GIS capabilities in mapping of performance indicators of "per capita space" and "per capita seat" is shown in Figure 1.

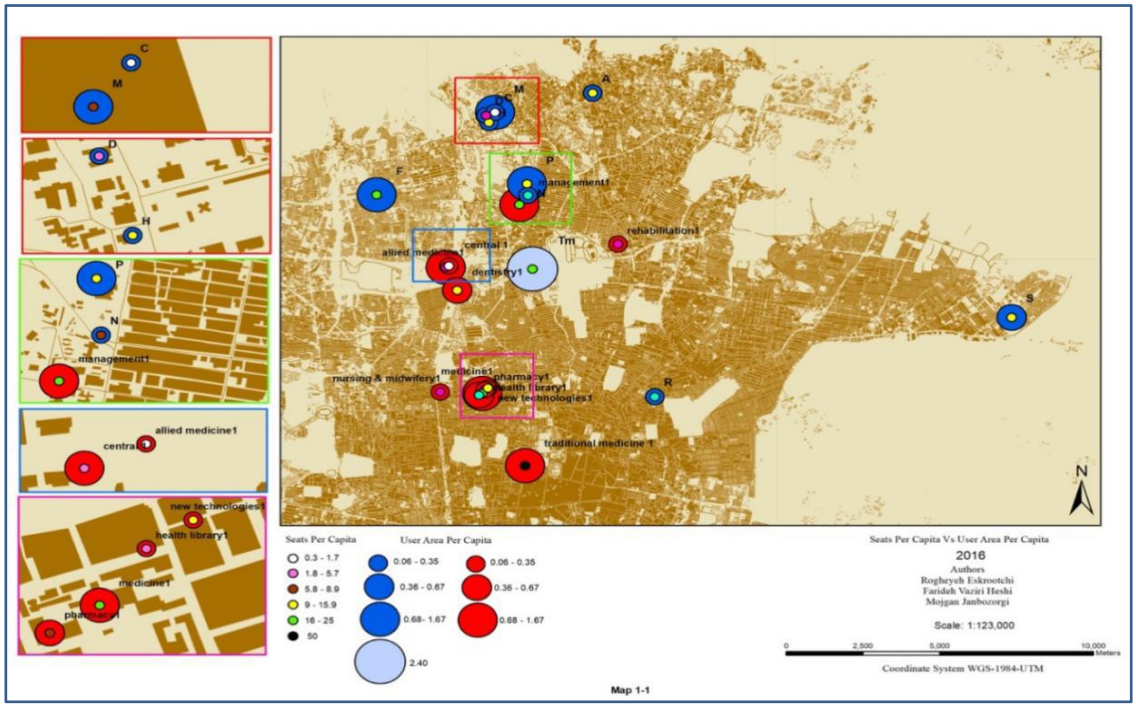

Figure 1: Per Capita Space and Per Capita Seats in the Libraries

It is observed in Figure 1 that due to the correlation between "per capita space" and "per capita seat", these two indicators are displayed together. In addition to display comparison, each library can be compared separately with other libraries in the same university, as well as across both universities. The values of "per capita space" were displayed in scale with four categories for SBUMS libraries (blue), and in scale with three categories for TUM libraries (red), measured in square meters units. For better understanding of the four categories of SBUMS libraries, they are specified in order of high to low, with scales "excellent", "good", "average" and "poor". The three categories of TUM libraries are in order of high to low with scales of "good", "average" and "poor". "Per capita space" at SBUMS libraries has highest value and is rated as excellent. The values of "per capita seat" was rated in order of high to low with scales "excellent", "very good", "good", "average", "poor" and "very poor". The status of these two indicators at SBMS libraries shows that the traditional medicine (TM) library has the highest "per capita space", is rated as "excellent" in "per capita seat"; there is 2.40 square

meters space per member at this library. It also has a “per capita seat” of 16 – 25% (i.e., the total number of seats of the library is 16-25% of all members). For every 4 to 6 persons there is a chair, which with respect to its available space and comparison with other universities with smaller space, and this is rated as very poor.

It is observed that the corresponding TM library in TUMS with much smaller space has the largest number of seats, for every two persons there is a chair. The two TM libraries utilizing the GIS image are compared, and the quality remarks mentioned earlier are confirmed. In addition, A (paramedical), H (health), and T (technology) libraries, with smallest space have relatively substantial number of seats. The primary benefit in all GIS maps is to be able to observe and compare every possible scenario in that area without any preconceived notions.

Figure 2 shows the per capita seats and percentage of seats occupied. A strong signal that almost all seats are occupied at all times (big circles) is observed, which results in patrons being not satisfied and likely not returning. When Figure 1 and Figure 2 are compared, it shows that some of the libraries with 100 percent occupied seats are the ones that actually had extra space and less seats.

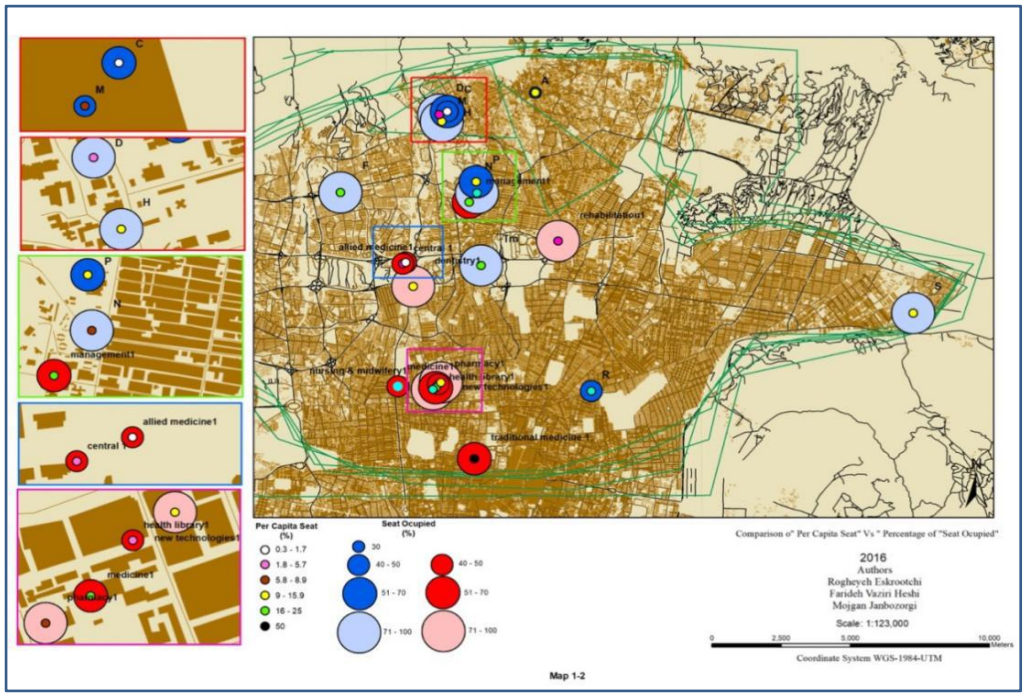

Figure 2: Per Capita Seats and Percentage of Seats Occupied

In terms of opening hours and demands, Figure 3 illustrates that that user satisfaction and the hours of the library are not necessarily correlated. It is observed that the big blue or red circles, which represent higher satisfaction, may have little white or pink dots, indicating they have the least number of opening hours. In contrast, in the smaller circles, with lower user satisfaction, we may see black dots indicating the libraries have longer opening hours.

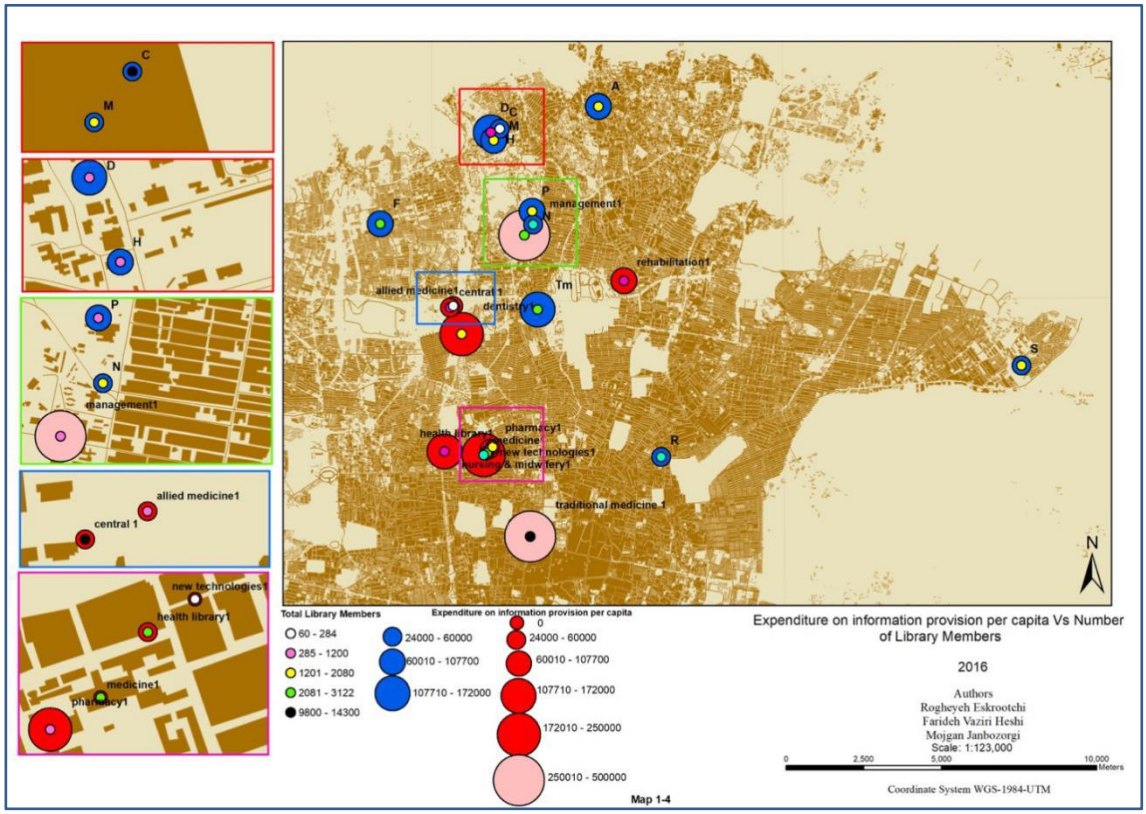

Figure 3: Opening Hours and Demand

Figure 4 compares the number of users in each library against the amount of information provision expenditure. In this scenario, it is shown that in spite of the expectation to observe libraries with more expenses to have more library members, there are libraries such as management (in TUMS) with the highest amount of expense yet among the least number of users. On the other hand, some libraries with the highest number of users and the least amount of expense are seen, such as the central libraries of both Universities.

Figure 5 compares the staff per capita and the number of users. It is observed that for both universities, TM libraries have the least number of users and therefore reasonably the largest number of staff per user. Although the total number of staff is not apparent in the figure, but the proportion is excellent, as shown by the largest circle of blue and pink with white dots in them. In contrast, if one observes the central libraries of both universities, one could conclude that the number of their users is between 9,800 to 14,300, however the libraries do not have sufficient staff to service the users. Nevertheless, one of the interesting points to note here is the libraries of "New Technology" for both universities. These libraries have relatively small number of users (depicted in yellow dots), yet has the smallest staff per capita, demonstrating that they are short in staff. These findings can be concluded quite robustly. The GIS visualization provides rich details to expand on further analysis.

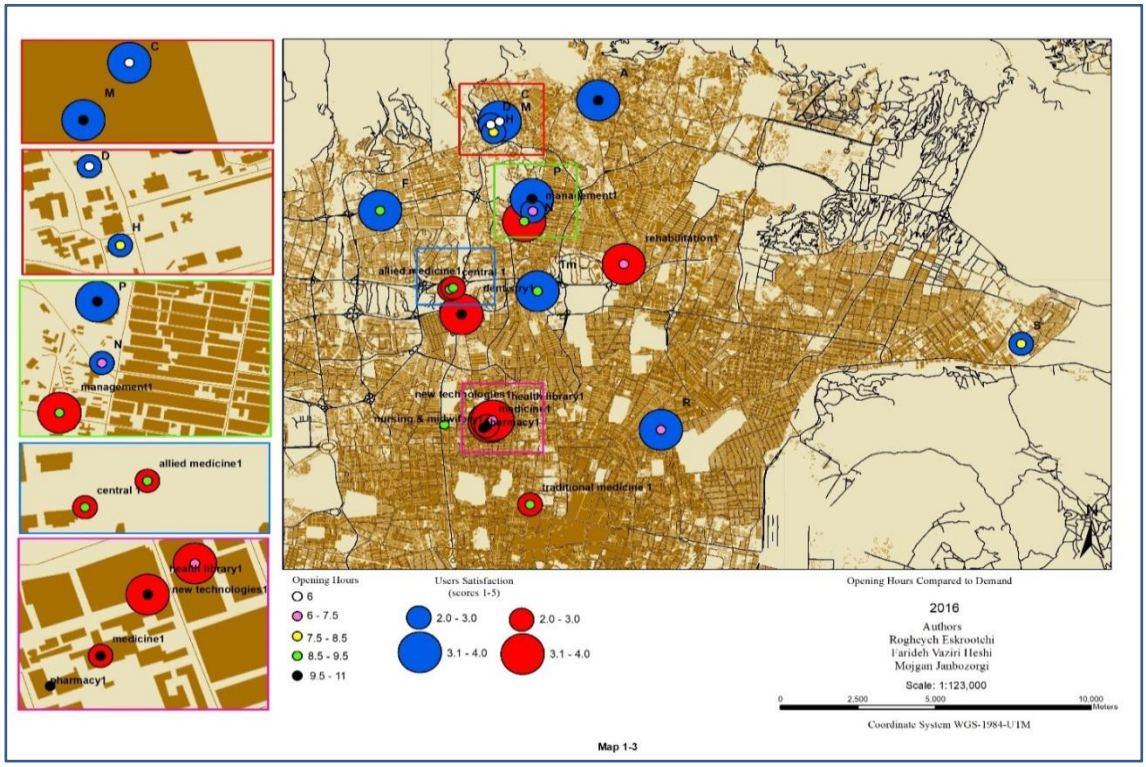

Figure 4: Expenditure on Information per Capita and Number of Library Users

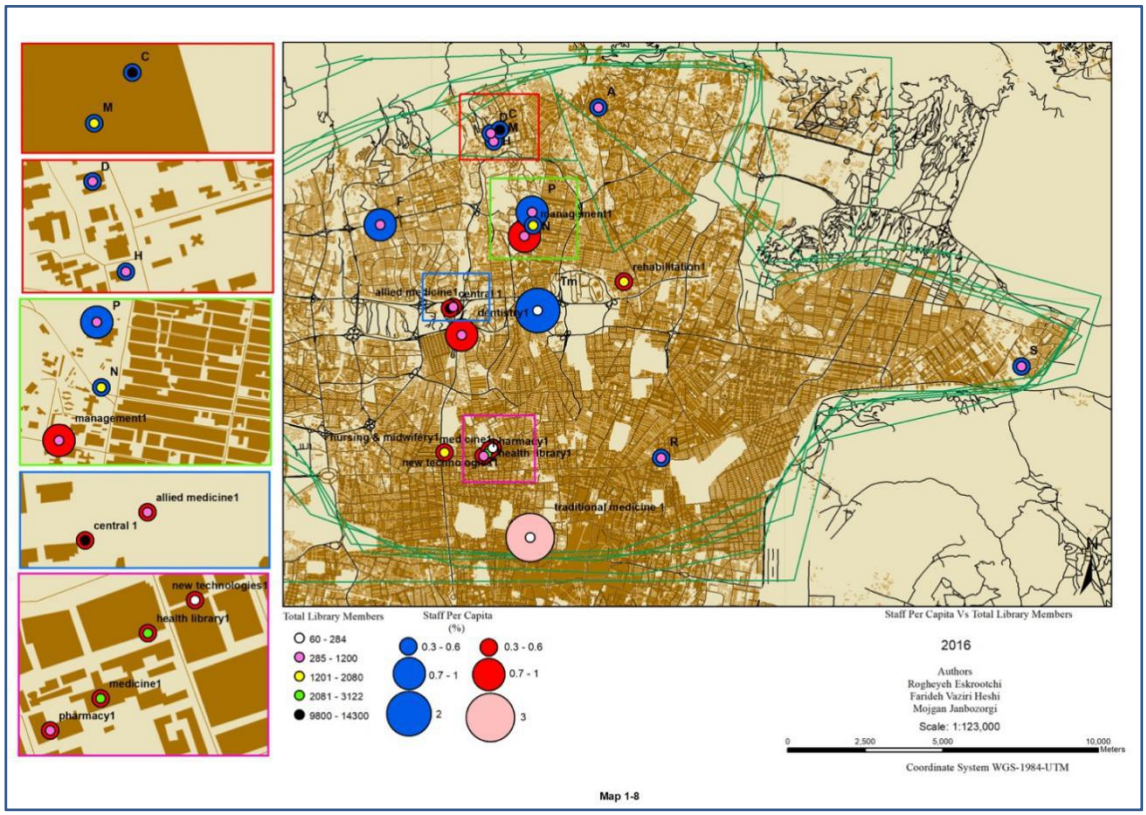

Figure 5: Staff per Capita and Number of Users

Figure 6 compares the quantity of resources that have been borrowed by users in contrast to the amount of unused resources. It clearly shows that libraries F (nutrition), S (health & safety) and P (pharmacy) from SBUMS are not using their resources optimally. But the libraries of TUMS have utilized a good proportion of their resources.

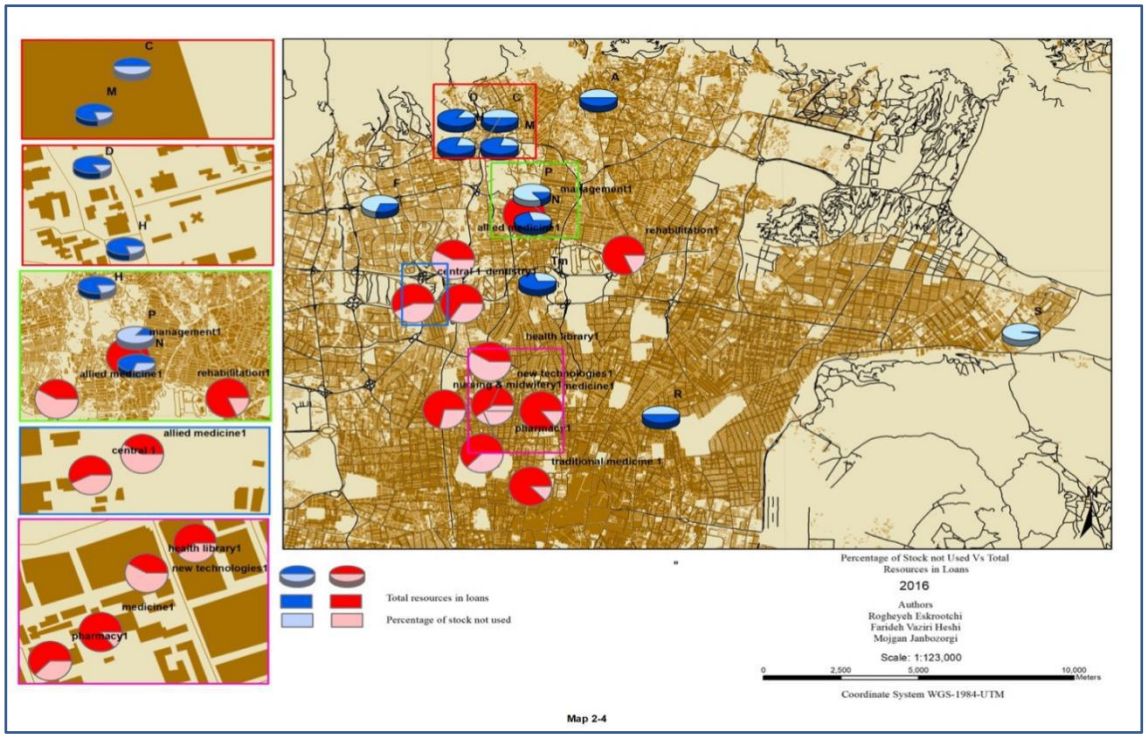

Figure 6: Percentage of Stock not Used and Total Resources in Loans

Figure 7 compares the ratio of acquisition costs with respect to staff costs. It demonstrates that those libraries with big circle representations are spending more money on resources for the library than on the staff, which would make more sense since the main role of the library is to provide the needed materials for their patrons. In contrast, there are libraries with small circles indicating more cost incurred on the staff than on the acquisitions of materials. The smaller dots show the number of staff, the white dots denote less number and the black dots denote larger number.

Finally Figure 8 compares the ratio of acquisition speed with respect to media processing speed. It demonstrates that in libraries such as S (health & safety) in SBUMS, this ratio is perfectly proportional. But at some other libraries this ratio is not appropriate. For example, in P (pharmacy) library at TUMS, the speed of acquisition is much higher than the processing speed to make the media available for use. In contrast, the speed of acquisition in D (dentistry) library in SBUMS in contrast to their processing speed is almost zero, which means that the library does not have that much resources to process.

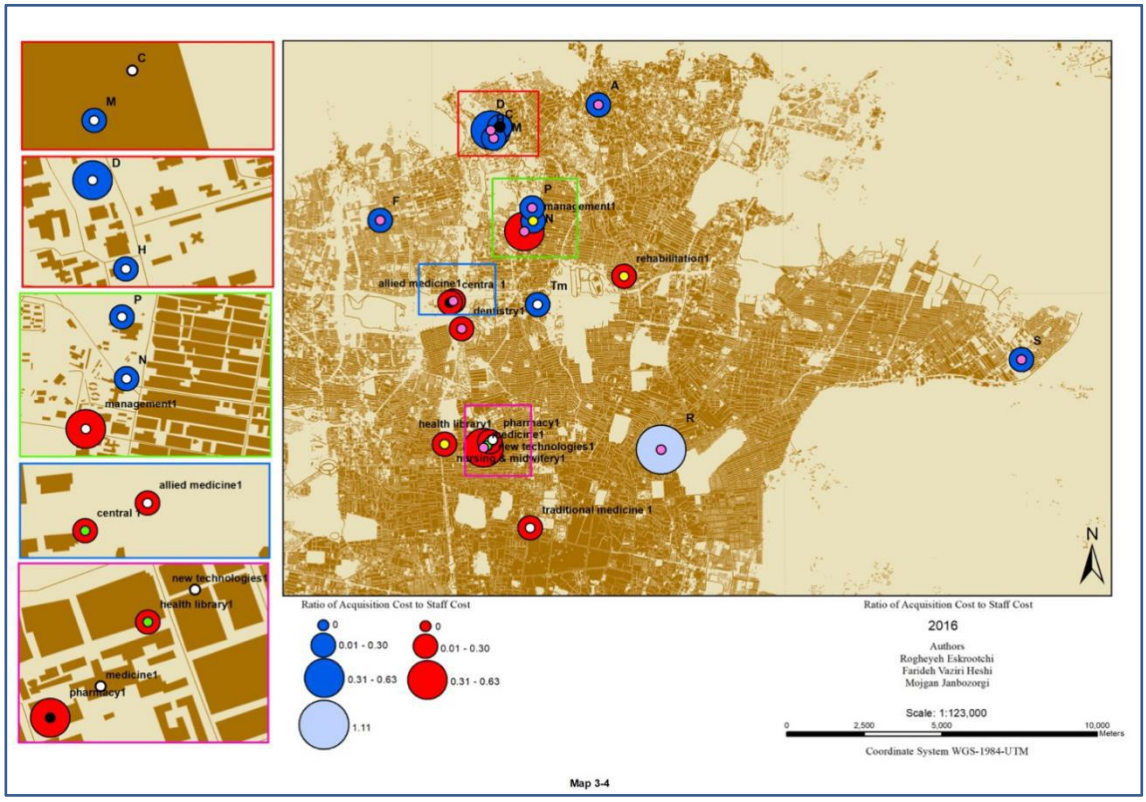

Figure 7: Ratio of Acquisition Costs to Staff Costs

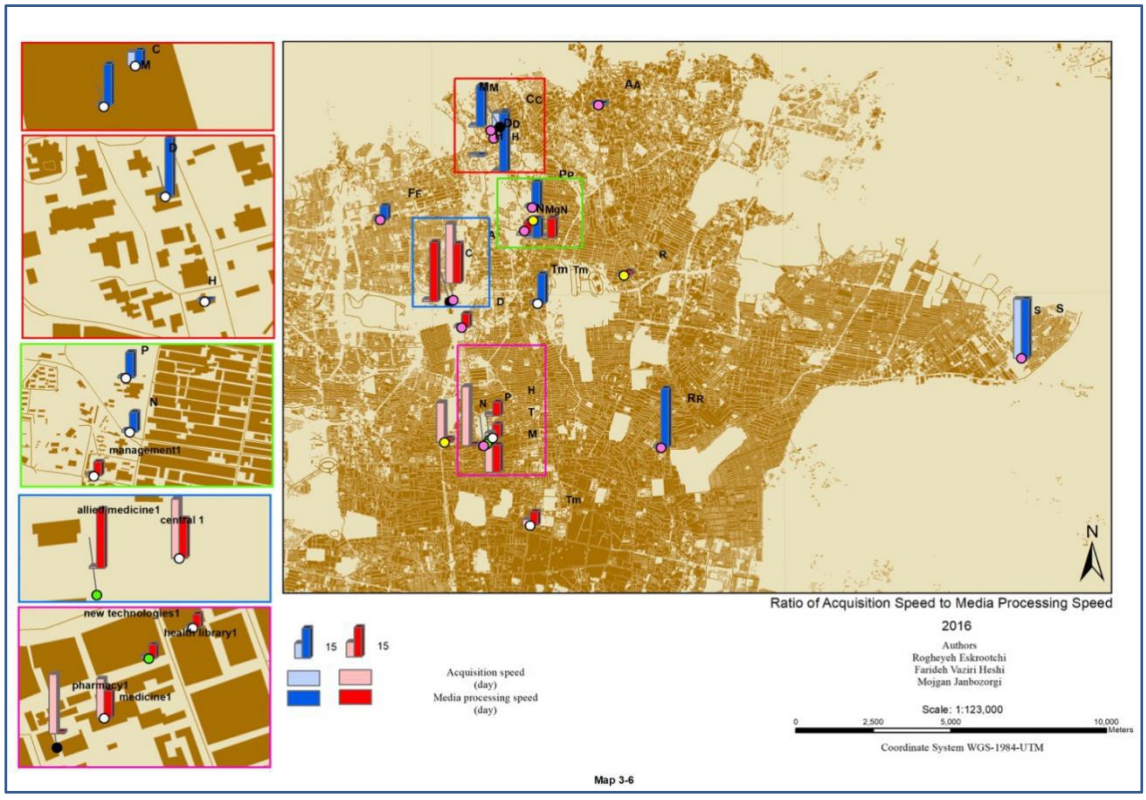

Figure 8: Ratio of Acquisition Speed to Media Processing Speed

DISCUSSIONS

A direct correlation between the two indicators “per capita space” and “per capita seat” is rational. Therefore it is expected that by an increase in per capita space, per capita seat may also increase and vice versa. However, it was observed that some of the libraries in this research do not display such a correlation. The libraries of paramedical (A) and health (H) colleges of SBUMS, as well as the library of new medical technologies (T) college of TUMS with the lowest per capita space, have been rated by a scale of “good” for per capita seat (9 to 15.9%), therefore it can be said that there is one seat per 6-11 people at these libraries Or the central library (C) of TUMS with the scale of “good” for per capita space (0.68 to 1.67 square meters), has been rated by a scale of “poor” for per capita seat (1.8 to 5.7%), thus it can be said that there is one seat per 17-55 people at this library. Generally, with a look at the Figures, it can be realized that apart from the traditional medicine libraries (TM) of both SBUMS and TUMS, the status of these two indicators at the other libraries were almost the same. In a study in which 15 selected performance indicators were measured for college libraries and technical colleges in Poland (Derfert-Wolf et al. 2003), the indicator “per capita space” was reported 0.27 square meters per person at college libraries, that placed in the range of the lowest value of per capita space (0.06 to 0.35 square meters) at both libraries of SBUMS and TUMS. In the same study done in Poland (Derfert-Wolf et al. 2003), the indicator “per capita seat” at college libraries showed that there are 63.59 people per seat, this finding is almost similar to the findings on the lowest range of seats and space belong to the central library of SBUMS. Indeed, plenty of space and seats in college libraries for users to study and work with computer is necessary. For example, the traditional medicine (TM) library of TUMS with the highest range of space per capita among the university’s libraries and per capita seat of 50 percent, allowing two people per seat, was ranked excellent on both indicators. Libraries, in which the per capita space is low, can be expanded by budget appropriation in order to increase the area of library, eliminate the unusable spaces (such as the library space dedicated to the physical library catalogue) and change the library layout (e.g. eliminating the large empty spaces between shelves). In libraries that the value of per capita seat is low, a budget can be considered to provide sufficient number of seats. Moreover, with enough space in library, the number of the seat can be increased.

Another indicator that demonstrates the lack of resources is the percentage of the time that seats are occupied. Many medical libraries are short in the number of seats for the users. GIS shows that some libraries have seats occupied most of the time because they do not have enough seats such as in C (central) and D (dentistry) libraries of SBUMS. This has been visualized in Figure 2 which clearly shows many big circles (100 percent occupied) with white and pink dots (the smallest number of seats), for example the rehabilitation (R) library of TUMS , having big circles and pink dots in the middle.

The study shows that GIS is capable of overlaying several layers thereby revealing the resulting intersections. For instance, if “per capita seat”, “ per capita space” and “percentage seat occupied” are overlaid, it is observed that many universities with large amount of space availability have 100 percent occupied seats. Having the “per capita seats” of these universities suggests that these libraries should reconsider their usage of space and try to locate more number of seats.

As for the number of library members, a correlation between this indicator and cost Is expected. However it can be clearly seen in Figure 4 that the big circles with white or pink dots inside indicates high expenditure and small number of users. These results show that

that the library is spending large amount of resource for small number of users.

To find out whether longer library hours would lead to more user satisfaction, the two layers namely " library hours " and "satisfaction" were overlaid. Interestingly, the pharmacy (P) library of TUMS with longest library hours (i.e. 11) received the least measure of satisfaction. On the other hand, the central (C) library of SBUMS with the least number of hours (6) had the highest measure of satisfaction.

With regard to indicator "per capita staff", there is a direct correlation between the number of library members and the number of library staff. However, it was observed that despite the traditional medicine (TM) of TUMS had the lowest number of members, it was allocated the highest per capita staff, and conversely, the central (C) libraries of both universities with the highest number of library members showed the lowest per capita staff. In general, the measure of this indicator at the libraries of both universities was almost the same. The collected annual data by LISU (Library and Information Statistics Unit) at Loughborough University in 2010-2011 reported that the total number of full-time staff members in new colleges was 141 and the total number of members was 33381 (SCONUL 2012). Therefore, the per capita staff was calculated at 0.4% which placed in range of the lowest values for per capita staff at libraries for both SBUMS and TUMS (0.3 to 0.6 %). At the libraries in which the number of library members is high but the number of staff members is low, a budget can be requested for staffing, if possible.

One would expect that libraries would allocate more budget on library acquisitions than on library staff, therefore in Figure 7 the large circles such as rehabilitation (R) of SBUMS illustrates an excellent condition. On the contrary, all libraries with small circles especially with light dots (small number of users) are not managed properly.

With regard to acquisition versus the media speed of processing, Figure 8 shows a proportional ratio. Hence, by observing some examples such as pharmacy (P) library of TUMS or dentistry (D) library of SBUMS, one would realize that the process is being delayed for a long time before another one takes place. Regardless of what the process is, both "purchase delay" and "resources inaccessibility" both reflect an inefficient library system.

CONCLUSIONS

In this study numerous interpretations and analysis could be conducted about indicators taken from GIS images. Since detailing the findings related to indicators at all libraries is beyond the scope of this study, the authors encourage readers to refer to the GIS images in order to get access to the respective details and items. Indeed, the maps created by GIS are similar to road maps in guiding people according to their needs and responding to their questions - it helps people to reach a common goal and make smarter decisions from the data. The most important capability of GIS in mapping the performance indicators is that it displays the indicator into visualizations and clear images (with high accuracy and wide domain of analysis and interpretation). With this unique capability, GIS reveals deeper insights into data, such as patterns, relationships and situations that might be missed in a spreadsheet. The analysis process could be very tedious and the presentation of findings would be less appealing if data are shown in tables and graphs format. In addition, displaying the indicators with the use of symbols in different sizes, and in some cases with colour changes in ArcGIS software, not only facilitates the

comparison of libraries, but also the general situation of studying indicators can be interpreted and understood by a look at the produced images, lending new perspectives to users' insight. Putting the layers of different database is also another potential capability of GIS in indicator analysis. The capacity indicator analysis in mapping is one of the capabilities GIS has, among its many other applications which has been used in this study.

The current study has used map format for representing the library indicators to highlight the capabilities of GIS and make the librarians familiar with this system. This paves the way for applying this useful and flexible technology in libraries and information centres. Given the fact that the available literature has validated the enormous potential of GIS technology, it should be further researched from various perspectives. Some important areas for future studies may include, measurement of performance indicator using the same methodology in other libraries and subsequently implementation of this assessment against international standards. In addition, measurement of performance indicators in other libraries in other countries may also be compared.

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REFERENCES

ArcGIS resources. 2019. Available at: https://pro.arcgis.com/en/pro-app/get-started/get-started.htm.

Bavakutty, M. and Majeed, A.K.C. 2005. *Methods for measuring quality of libraries.* New Delhi: Ess Ess publications.

Bishop, B. W. and Mandel, L.H. 2010. Utilizing geographic information systems (GIS) in library research, *Library Hi Tech*, Vol. 28 No. 4, pp. 536-547. Available at: https://doi.org/10.1108/07378831011096213.

Brundin, M. R. 2007. Using a Geographic Information System to analyze public library performance measures. Paper presented at the *American Society for Photogrammetry and Remote Sensing (ASPRS) Annual Conference,* 2007, at Tampa, Florida.

Dennis, S.F., Gaulocher, S., Carpiano, R. M. and Brown, D. 2009. Participatory Photo Mapping (PPM): Exploring an integrated method for health and place research with young people. *Health and Place*. Vol. 15, no. 2: 466-473.

Derfert-Wolf, L., Dobrzynska-Lankosz, E., Dziadkiewicz, W., Gorny, M., Gorska, E., Gorski, M. M., Jazdon, A., Sokolowska-Gogut, A. and Wildardt, T. 2003. *Library and Information Science Research.* Vol. 27, no. 87: 17-28.

Elliott, R. 2014. Geographic Information Systems (GIS) and libraries: Concepts, services and resources. *Library Hi Tech News.* Vol. 31, no.8: 8-11.

Hertel, K. and Sprague, N. 2007. GIS and census data: Tools for library planning. *Library Hi Tech.* Vol. 25, no. 2: 246-259.

Horwitz, T. 2012. Looking at the Battle of Gettysburg through Robert E. Lee's eyes. *Smithsonian Magazine*. Available at: www.smithsonianmag.com/history/looking-at-the-battle-of-gettysburg-through-robert-e-lees-eyes-136851113/?all>.

Keddem, S., Barg, F.K., Glanz, K., Jackson, T., Green, S. and George, M. 2015. Mapping the urban asthma experience: Using qualitative GIS to understand contextual factors affecting asthma control. *Social Science & Medicine*, Vol. 140: 9-17. Available at: https://doi.org/10.1016/j.socscimed.2015.06.039.

Kim, H. K. 2018. Using Geographic Information Systems (GIS) to optimize delivery system services for BCCLS libraries. Paper presented at the *SIGMA XI Student Research Symposium,* 27 April 2019. SIGMA XI - The scientific research society. Available at: https://digitalcommons.montclair.edu/sigma-xi/2019/poster-1/51/.

Kong, N., Fosmire, M. and Branch, B. D. 2017. Developing library GIS services for humanities and social science: An action research approach. *College & Research Libraries*, Vol. 78, no. 4: 413-427.

Larsgaard, M. L. 1998. *Map librarianship: An introduction.* Westport, CT: Libraries Unlimited.

LaRue, E.M. 2004. Using GIS to establish a public library consumer health collection. *Biomedical Digital Libraries*, Vol. 1, no.1: 3.

Liu, F., Lin, A., Wang, H., Peng. Y. and Hong. S. 2016. Global research trends of geographical information system from 1961 to 2010: A bibliometric analysis. *Scientometrics,* Vol. 106: 751-768.

Murad, A.A. and Tomov, D.T. 2012. Institutionalization and internationalization of research on the applications of the geographical information systems in health planning. *Scientometrics*, Vol. 91: 143-158.

Omidifar, S. and Moosavizade, Z. 2009. Measuring library services's quality levels of psychology & education faculty at Allameh Tabatabai University by LibQUAL model. *Information Research and Public Libraries*, Vol. 15, no. 4: 61-80.

Ou, R., Pan, H. and Huang, Y. 2017. Research on intelligent library document navigation system based on GIS. *Advances in Engineering Research*, Vol. 123: 223-227.

Pinto, L.G. and Ochoa, P. 2019. Aliging libraries` performance with sustainable development goals: a methodological proposal. Paper presented at the *4th World Conference on Qualitative Research*, 16-18 Oct 2019, Porto, Portugal.

Poll, R. and Boekhorst, P. 2007. *Measuring quality: Performance measurement in libraries.* Munich: K.G. Saur.

Pournaghi, R. 2017. GIS as a supporting instrument for making decisions about the library sources collection management. *Collection Building*, Vol. 36, no. 1: 11-19.

Pournaghi, R., Babalhavaeji, F., Garagozlo, A. R. and Hariri, N. 2013. Proposed plan for mapping library collection through GIS: A case study of the Central Library of Tehran University. *Journal of Health Administration*, Vol. 16, no. 53: 22-35.

Pournaghi, R. and Pournaghi, L. 2010. GIS applications and role in libraries and information centers' managerial decisions. Paper presented at the *National Conference of Geophysics,* 2010, Tehran, Iran. (in Persian). Available at: http://www.civilica.com/Paper-GEO89-GEO89_038.html.

Sadeghnejad, M. 2016. *Geographic Information System & semote sensing* (in Persian). Available at: http://gis-rs-world.blogsky.com/1392/03/13/post-14.

SCONUL. 2012. *Annual Library Statistics 2010-11.* Available at: https://www.sconul.ac.uk/sites/default/files/documents/ALS1011.pdf.

Shen, Y. 2018. Library Space Information Model Based on GIS — A Case Study of Shanghai Jiao Tong University. *Information Technology and Libraries*, Vol. 37, no. 3: 99-110.

Townley, G., Pearson, L., Lehrwyn, J.M., Prophet N.T. and Trauernicht, M. 2016. Utilizing participatory mapping and GIS to examine the activity spaces of homeless youth. *American Journal of Community Psychology*, Vol. 57, no. 3/4: 404-414.VAa.

Wood, S. and Browne, S. 2007. Convenience store location planning and forecasting — a practical research agenda. I*nternational Journal of Retail and Distribution Management,* Vol. 35, no. 4: 233 -255.

Xia, J. 2004a. Library space management: A GIS proposal. *Library Hi Tech*, Vol. 22, no. 4: 375-382.

Xia, J. 2005b. Locating library items by GIS technology. *Collection Management*, Vol. 30, no. 1: 63-72.

Xia J. 2005c. Visualizing occupancy of library study space with GIS maps. *New Library World*, Vol. 106, no. 5/6: 219-233.

Zhang, Y. and Liu, L. 2019. Temporal point pattern analysis of human activities using GIS methods: A case study of library visting activities in Chengdu city, China. *The Professional Geographer*, Vol. 71, no. 4: 738-750.

Zografos, K.G. and Androutsopoulos, K.N. 2008. A decision support system for integrated hazardous materials routing and emergency response decisions. *Transportation Research Part C: Emerging Technologies*, Vol. 16, no. 6: 684-703.

APPENDIX A

List of Libraries in This Study

Libraries of Tehran University of Medical Sciences

1. Central Library ©
2. Allied medicine Library (A)
3. Dentistry Library (D)
4. Health Library (H)
5. Medicine Library (M)
6. Management Library (Mg)
7. Pharmacy Library (P)
8. Advanced technologies in medicine Library (T)
9. Rehabilitation Library ®
10. Nursing & midwifery Library (N)
11. Traditional medicine Library (TM)

Libraries of Shahid Beheshti University of Medical Sciences

1. Central Library (C)
2. Allied medicine Library (A)
3. Dentistry Library (D)
4. Health Library (H)
5. Medicine Library (M)
6. Nutrition & food sciences Library (F)
7. Pharmacy Library (P)
8. Health, Satisfy, Environment Library (S)
9. Rehabilitation Library (R)
10. Nursing & midwifery Library (N)
11. Traditional medicine Library (TM)

APPENDIX B

List of 40 performance indicators

1. Per capita space
2. Per capita Seat
3. Opening hours and demand
4. Expenditure on information per capita
5. Availability of required titles
6. Percentage of rejected sessions
7. Ratio of requests received to requests sent out in interlibrary lending
8. Immediate availability
9. Staff per capita
10. Direct access from the homepage
11. Market penetration
12. User satisfaction
13. Library visits per capita
14. Seat occupancy rate
15. Number of content units downloaded per capita
16. Collection use (turnover)
17. Percentage of stock not used
18. Loans per capita
19. Percentage of loans to external users
20. Attendances at training lessons per capita
21. Reference questions per capita
22. Attendances at events per capita
23. Cost per user
24. Cost per visit
25. Cost per use
26. Ratio of acquisitions costs to staff costs
27. Cost per document processed
28. Cost per download processes
29. Acquisition speed
30. Media processing speed
31. Employee productivity in media processing
32. Lending speed
33. Interlibrary loan speed processes
34. Reference fill rate
35. Shelving accuracy
36. Percentage of acquisitions expenditure spent on the electronic collection
37. Percentage of library staff providing and developing electronic services
38. Attendances at training lessons per staff member
39. Percentage of library means received by special grants or income generation
40. Percentage of institutional means allocated to the library