# Analysis of the Physical Behavior of Library Users in Reading Rooms through GIS: A Case Study of the Central Library of Tehran University

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*Abstract*—Taking into account the significance of measuring the daily use of the study space in the libraries in order to develop and reorganize the space for enhancing the efficiency of the study space, the current study aimed to apply GIS in analyzing the study halls of the Central Library and Document Center of Tehran University in order to determine how study desks and chairs were used by the students. The study used a combination of survey-descriptive and system design method. In order to gather the required data, survey-descriptive method was used. For implementing and entering data into ArcGIS and analyzing the data and displaying the results on the maps of the study halls of the library, system design method was utilized. The design of the spatial database of the use of the study halls was measured through the extent of occupancy of the space by the library users and the maps of the study halls of the central library of Tehran University as the case study. The results showed that Abooreyhan hall had the highest rate of occupancy of the desks and chairs compared to the other halls. The Hall of Science and Technology, with an average occupancy rate of 0.39 for the tables represented the lowest number of users and Rashid al-Dins hall, and Science and Technology hall with an average occupancy rate (0.40) had the lowest number of users for seats. In this study, the comparison of the space occupied at different periods in the morning, evenings, afternoons, and several months was performed through GIS. This system analyzed the space relationships effectively and efficiently. The output of this study would be used by administrators and librarians to determine the exact extent of use of the equipment of the study halls and librarians can use the output map to design the space more efficiently at the library.

*Keywords*—Geospatial Information System, Spatial analysis, Reading Room, Academic libraries, Library's User, Central Library of Tehran University.

## I. INTRODUCTION AND PROBLEM STATEMENT

THE concept of library as a place for studying has been fortified by the fact that many users sit there and study their own sources. An investigation on the extent of in-library use of the materials in Calabar University demonstrated that non-library sources were used more than those of the library [1]. The findings of another study showed that academic libraries users would prefer single study desks to group ones. They were more interested in making use of the desks with electrical and internet connections and they liked group study rooms [2].

Furthermore, a new method was employed in designing and re-organizing the study hall with emphasis on several issues.

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For one thing, the number of group study rooms was increased. The libraries are no longer viewed as a calm place for studying; it is, however, conceived of as a place where a wide range of users visit for various purposes and they might talk and consult with each other [3]-[6]. An increase in the group research space in the central library of Tehran University is observed: there is a section next to the manuscripts called "researcher's hall" which is used for consultation and conversation with university professors and postgraduate students.

Carlson put forth the idea of "deserted libraries". From his point of view, modern technological advances would lead to an increase in virtual use of the libraries and a decrease in their physical use. It seems that most students in their dormitories and through internet connections take advantage of the prevailing sources and documents [7].

In addition, the results of previous studies have indicated that the students use the internet to access information which does not belong to the library [8] (e.g. Google). Furthermore, with the advent of such communications technologies as cell phone, the libraries try to take advantage of them in introducing and offering their services. For instance, the experience of Ryserson Library showed that there is a growing increase in using cell phones and relevant intelligent technologies among students and this technology had the potential of offering more optimal services to the library users [9]. New challenges of the library study space and selected solutions for its designing do, by no means, matter. What is of paramount significance is the urgent need to physical space in libraries [10] and to searching for recording the standards and re-organizing the library space based on them.

In-library study space is determined considering the space of the complex, working space of the staff, services space, and similar cases. The study space is often prioritized over the complex space. In order to keep balance in dividing the library space into several sections, the library designers and constructors take advantage of the booklet published by Association of College and Research Libraries for evaluating the study space [11]. Nevertheless, there are a wide range of factors outside the library that would make an impact on its use (for instance, the computer labs, small specialist libraries, and study rooms which are available in the university context). Furthermore, the recent developments in multimedia have complicated the design of the library space [12], [13]. Today, several libraries are frequently being re-designed.

In order to study the library space, measuring the extent of

daily use of the study space is necessary which should entail recording the rate of occupancy of each study space or each facility e.g. a desk, a chair, a sofa, and single desks at specified time intervals within a time span. These measurements underlie the extension of the libraries or their re-organization. In this way, the libraries can moderate their condition in order to reach maximum efficiency.

The current study tried to take advantage of geospatial information system in order to visualize the extent of use of the study space and occupancy of the study halls facilities since geospatial information system is capable of displaying a large bulk of statistical information in the form of tables and diagrams and various combined images. The library managers and librarians can utilize it in making informed decisions for improving the condition of the study halls. Bearing this in mind, the current study primarily aimed to employ GIS in analyzing the space of the study halls of the document center and central library of Tehran University and to determine the extent of use of the desks and chairs by the users.

## II. CAPABILITIES OF GIS FOR ANALYZING THE STUDY SPACE OF THE LIBRARIES

Geographical information system which is currently called Geospatial Information System is used to gather, store, analyze and display the spatial and graphical data [14]. The data are geographical-spatial in nature (e.g. they are related to geographical spaces). However, geospatial information system can integrate geographical-spatial data with attribute data or descriptive statistics. Geospatial information system is growingly accessible and its unlimited packages are freely downloadable. Hence, libraries and other similar institutes can take advantage of it.

Nowadays GIS is used as a tool to measure and analyze the library services [15]. There are even some materials regarding implementing GIS in order to use geographical sources in libraries [16]-[21]. GIS was introduced as a tool for graphical displaying of research data in the field of Knowledge and Information Sciences. The data may include demographic information of the users of the libraries and document centers which is used for their simpler designing [22]-[30]. Moreover, the data might include those which are used in the library [2], [22], [23], [31]. In this case, GIS can cover the data used in the plan of different floors of the library. This would provide a much richer picture of how the facilities of this system can be used than those of traditional tables and diagrams. The current study used this idea for creating a searchable spatial database for the extent of use of the space and study space occupancy by the library users.

A large body of studies have demonstrated that GIS was implemented through making use of in-library spatial data on a single case [2], [18], [24], [28], [31]-[35]. Accordingly, the current study was focused on the document center and central library of Tehran University. The study halls in the libraries are generally designed in two ways: either the study hall is surrounded by walls or it is located at the center of the library and is surrounded by book shelves (or stacks). In the central library of Tehran University, there are four study halls which are all located at the center and are surrounded by book shelves. However, less space seems to exist for expanding the study halls in this library and the space difficulty would emerge as result of complex development and an increase in the number of users. As a result, analyzing the study space for optimizing it and future planning seems to be of utmost significance. This is possible through utilizing such tools as GIS. GIS facilitates measurement and is also considered as a powerful tool in depicting the measures and locations.

The primary purpose of the current study was as follows: employing GIS in analyzing the space of facilities of the study halls of Tehran University central library. The secondary purposes of the current study were as follows: determining the extent of users' use of each study desk and chair in different months and the extent of users' use of each desk and chair existing in the study halls.

## III. METHODOLOGY AND DATA COLLECTION PROCEDURES

The current study made use of a combination survey-descriptive and system design methods. In order to collect the required data, survey-descriptive method was used. In order to implement and feed the information and data into ArcGIS software, analyze the data, and display the results on the study halls maps, system design method was utilized.

In the case under the study (the central library of Tehran University), the following procedures were taken:
– Preparing the map of the central library;
– Modifying the maps of the library study halls according to the recently made changes;
– Drawing the maps of the library study halls in Auto CAD software in order to modify the required parts and digitizing the maps;
– Observing and drawing the existing facilities and equipment in each hall (desk, chair, shelf, etc.) on the maps of library study halls and converting them to digital format through appropriate elements by Auto CAD;
– Processing attribute data (the extent of space occupancy) by SPSS;
– Feeding the spatial and attribute data into ArcGIS software and creating typology;
– Processing information layers and creating a spatial database for the library study space and receiving the output.

In order to collect the required data considering the users' use of the library study halls, the data were collected within three weeks (the third week of October, the third week of November, and the third week of December) through observing the users while they were using the desks and chairs in Abooreyhan, Rashidodin Hamedani, Eghbal Lahoori (Reference Section), Jamal Zadeh (Sciences and Technology) halls 10 times a day (every one hour from 8:15 till the end of the working day of the hall). Taking into account the interviews with the authorities of different sections of the library, it was found that almost all desks and chairs were full from the beginning till the end of the working day in January; as a result, the data were collected in the first three weeks of

academic year through census report. A checklist was used to examine and record the user's extent of use of the available desks and chairs in the study halls in the form of maps at specific hours. As the checklists were designed to measure the current status of the libraries and thereby, reflected the current status of their space, they seemed to enjoy higher validity. In order to conduct descriptive statistics, the collected data were fed into SPSS (version 15). In order to describe the data, common methods in descriptive and inferential statistics e.g. frequency table, calculating statistical indices and plotting were used. Having processed the data by the aforementioned software, the data were prepared to be fed into ArcGIS software. Following that, the geospatial information database was formed. Geospatial information systems utilize various types of software in order to display and analyze the spatial data. In the current study, ArcGIS was particularly used to implement the spatial information of the library and to form spatial database for the extent of occupancy of study space of the central library of Tehran University.

## IV. FINDINGS

What is presented in the following section is related to the way GIS was applied to analyze the space and facilities of the study halls of the document center and central library of Tehran University. Following it, the results for the extent of users' use of the available facilities (desks and chairs) in study halls in general and in terms of each hall in particular are presented. In order to examine the extent of use of facilities in different halls and analyze and present the results more precisely, a number of questions were first posed and the answers were provided.

To examine the extent of users' use of halls facilities, two main questions were addressed:

"Is the extent of the students' use of each chair and desk of the study hall similar?"

To answer this question, the results of Friedman test were used.

The second question was as follows: "Does the extent of users' use of each chair and desk of the study hall differ in various months?" in order to answer this question, one-way ANOVA was used for the average coefficient of occupancy for the chairs and desks on weekdays. Since the table related to the extent of occupancy of the chairs and desks was too bulky, it was not included in the discussion section and only the results for the comparison among the halls are presented.

Table I displays the average coefficient of occupancy for all chairs and desks. As it is observed, the highest occupancy coefficient belonged to Abooreyhan hall with more number of chairs and desks compared to other halls. The lowest occupancy coefficient was obtained by Sciences and Technology hall (0.39) and Rashid-o-Din and Sciences and Technology halls (0.40) for making use of desks and chairs, respectively.

Table II illustrates the comparison of the extent of use of desks and chairs in terms of users' gender. It was observed that in Reference hall, female users used the desks more than their male counterparts whereas in Sciences and Technology

and Abooreyhan halls, male students occupied the desks more than their female counterparts. Similar results were obtained for the chairs. (Rashid-o-Din Hamedani hall was not included since the male and female sections were not secluded in the sitting space).

TABLE I
COMPARISON OF THE NUMBER OF FACILITIES AND THE EXTENT OF THEIR USE (OCCUPANCY COEFFICIENT) IN STUDY HALLS

| Name of hall | Number of desks | The average occupancy coefficient desk | Number of chairs | The average occupancy coefficient chair |
|---|---|---|---|---|
| Rashid-o-Din Hamedani | 8 | 0.48 | 39 | 0.40 |
| Reference | 13 | 0.45 | 33 | 0.44 |
| Sciences and Technology | 30 | 0.39 | 164 | 0.40 |
| Abooreyhan | 98 | 0.54 | 204 | 0.55 |

TABLE II
COMPARISON OF THE NUMBER OF FACILITIES AND THE EXTENT OF THEIR USE (OCCUPANCY COEFFICIENT) IN DIFFERENT HALLS IN TERMS OF USERS' GENDER

| Gender | Females | | Males | |
|---|---|---|---|---|
| Name of hall | Number of desk | The average occupancy coefficient desk | Number of desk | The average occupancy coefficient desk |
| Reference | 6 | 0.50 | 7 | 0.42 |
| Sciences and Technology | 16 | 0.38 | 14 | 0.42 |
| Abooreyhan | 48 | 0.51 | 50 | 0.58 |
| | Number of chairs | The average occupancy coefficient chairs | Number of chairs | The average occupancy coefficient chairs |
| Reference | 12 | 0.50 | 21 | 0.42 |
| Sciences and Technology | 80 | 0.38 | 84 | 0.42 |
| Abooreyhan | 100 | 0.51 | 104 | 0.59 |

How can GIS be implemented for analyzing the used places by the students as well as the library facilities?

The findings showed that spatial observation and analysis of the extent the users make use of the library facilities entails several stages in geospatial information system. Accordingly, the following stages were considered

1. Collecting the data
2. Preparing the data
3. Entering the data into ArcGIS software and processing several information layers
4. Analyzing the data and creating geospatial maps
5. Geospatial searching for the occupancy extent of the facilities and receiving the output

Collecting the data includes two stages: attribute data (the occupancy extent of the chairs and desks), and spatial data (the maps of the halls and facilities of the library halls).

**Preparing the data for Entering into ArcGIS software**

Preparing the data for feeding into ArcGIS entails two procedures: preparing the geospatial data and attribute data.

**Preparing the geospatial data**

After collecting the data e.g. study halls maps and facilities, the data were prepared as follows:

- The maps of the study halls of the library building:
- Compatibility of the plan image of the library study halls

(in GPAG format) with the reality and modifying and updating them;

– Drawing the modified map of the library study halls plan in AutoCAD software in order to convert raster data into vector data;

– Creating several layers of the floor plans of the library in AutoCAD software (including sections, chairs, desks, etc.);

– Coding geospatial data (chairs and desks) on relevant layers

– Library facilities

– Designing the facilities of the library study halls by appropriate symbols in AutoCAD and at right places on the plan map of the library floors;

– Creating several layers of the facilities in AutoCAD software (chairs, desks, and other furniture);

– Coding several facilities in each layer (chairs and desks)

Fig. 1 displays samples of plan maps of the library floor and the relevant facilities which were drawn in AutoCAD software and prepared to be fed into ArcGIS software.
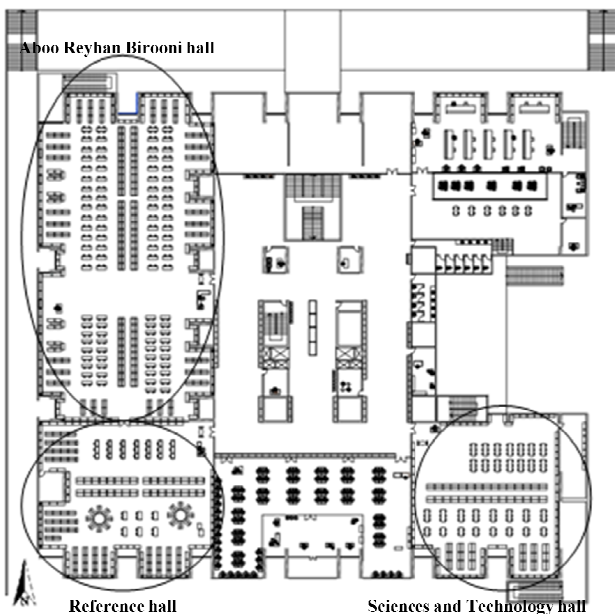


Fig. 1 The plan of the building and the facilities of the first floor of the Central Library of Tehran University

*Preparing the Attribute Data*

Having collected the data through conducting observation and analyzing them in SPSS software, the tables for the extent of use of chairs and desks were obtained. In order to prepare the data to be entered into ArcGIS software, the average use of them were estimated to be 0 and 1 within October, November and December. The extent of use of above %50 was considered as 1 and that of less than %50 was considered as 0. Then, this information, which was separately considered by coding each chair and desk, was screened and the relevant tables were prepared for chairs and desks.

*Entering the Data into ArcGIS and Processing Several Information Layers*

After drawing the data in AutoCAD software, the data (chair and desk facilities) were converted into a shape-file format while being entered into ArcGIS software. Each shape file (chairs and desks) had an attribute table. Their attribute and Excel (information) tables were associated in entering the data.

*Analyzing the Data and Creating Maps*

In order to make it possible to search and display the extent of use of chairs and desks geospatially through the database characteristics (association between tables), the table of average extent of use of chairs and desks within several months and in total was associated with the layers of chairs and desks (one-to-one association). In this sense, geospatial searching and observing of the extent of use of chairs and desks on the library map were possible.

*Geospatial Searching for the Sources and Receiving the Output*

Following the above steps, geospatial searching for the chairs and desks in different information fields was done through structured query language in the database in terms of several months. It was observed that while after finding each chair and desk, the place of its facilities is displayed on the maps of the library floors. Moreover, other supplementary three-dimensional analysis programs of ArcGIS allowed for three-dimensional observation of the chairs and desks in specific halls in terms of a particular month, with several information layers. In addition to visual output (in the form of images), attribute tables and diagrams were provided as well. A number of images resulting from geospatial searching for the facilities in terms of the extent of use in geospatial information system are presented below.
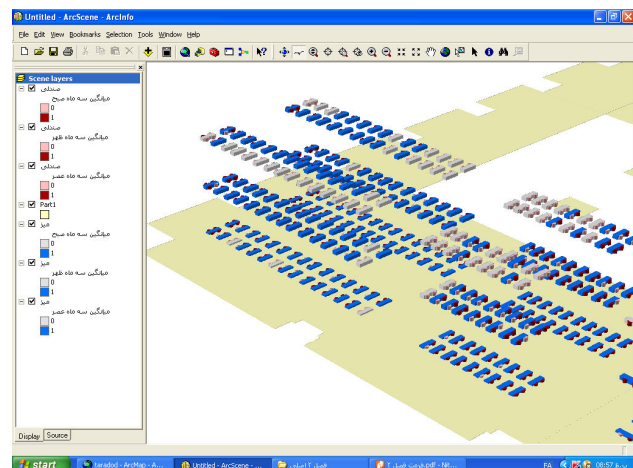


Fig. 2 Three-dimensional display of the average extent of occupancy of chairs and desks of Abooreyhan hall within three months (October, November, December) in the morning, noon, and afternoon

Fig. 2 displays the average extent of occupancy of the chairs and desks for Abooreyhan hall within the sampling

period. Different times of the day (morning, noon, afternoon) are shown in different layers from bottom to top. The extent of chairs occupancy above %50 is considered as 1 (in purple) and that of below %50 is considered as 0 (in pink). The extent of desks occupancy or no occupancy is shown in blue and gray, respectively.
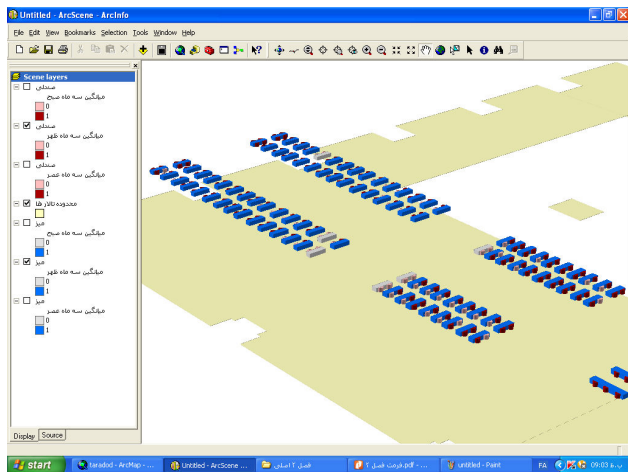


Fig. 3 Three-dimensional display of the average extent of occupancy of chairs and desks of Abooreyhan hall within three months (October, November, December) at noon

As Fig. 3 demonstrates, turning layers on and off could provide the information related to a particular month and time. In this way, several images could be obtained. Each image can be used for different analysis of the relevant library. This is a dynamic mechanism which allows the librarians to observe the extent of use of the facilities in different places and at different times (various months, various hours).
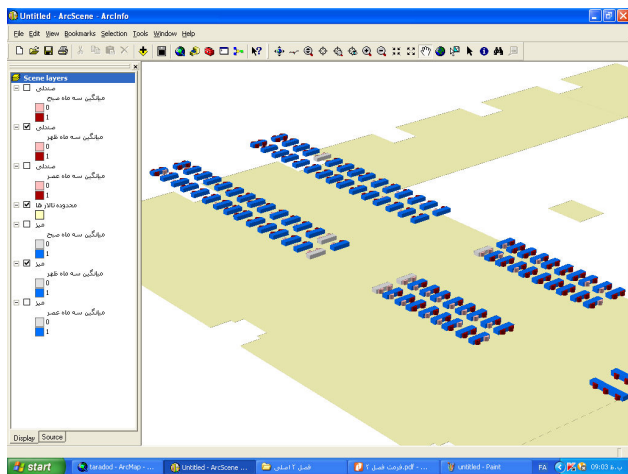


Fig. 4 Three-dimensional display of the extent of occupancy of the desks and chairs of first-floor halls of the library building within three months (October, November, December) in the morning, noon, and afternoon

Fig. 4 illustrates the extent of occupancy of the desks and chairs in different halls which are located on the first floor

within the sampling period. Different times (morning, noon, and afternoon) are demonstrated in different layers from bottom to top. The area of Sciences and Technology hall is determined at the front part while Reference hall is on the up right side and Abooreyhan is on the up left side. As it is shown, the highest extent of use occurred in Sciences and Technology and Reference halls at noon.
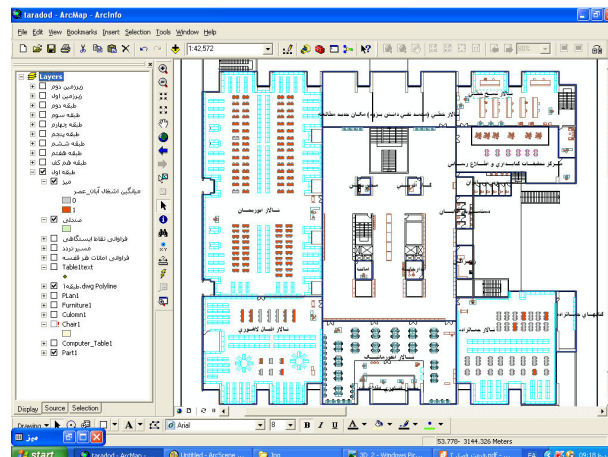


Fig. 5 Two-dimensional display of the average extent of occupancy of desks of the first-floor halls in November and in the afternoon

Fig. 5 displays the average extent of occupancy of the desks for the first-floor halls in November and in the afternoon. To display the average extent of occupancy of desks, gray and orange colors were used to show no occupancy and occupancy, respectively. As you can see, the highest extent of use of the desks belonged to Abooreyhan hall in November and in the afternoon.

## V. DISCUSSION AND CONCLUSION

Since the information related to the library study space is of spatial-temporal nature, GIS can be applied to study it. The library space can be depicted in the form of a map which is capable of displaying the plan of the floors and furniture. The current study was conducted in four halls through illustrating their study space by creating vector layers including physical elements e.g. chairs and desks with coordinates x, y, z. With regard to the extent of use of the facilities at different times of the day, the collected and analyzed data resulted in large tables in several types of statistical software. Reading and comprehending this huge bulk of information in large tables and diagrams is not easy; hence, GIS was employed which allows for displaying the spatial analysis and spatially searching for stored information as well as searching on the library map. In this sense, information can be readily received and understood through visually displaying of the analyses and large tables on the library maps.

The current study utilized GIS to compare the space occupied in the study hall within different time spans e.g. in the morning, noon, afternoon and several months. GIS could analyze the space occupancy effectively and efficiently.

Analyzing spatial data entails numerous cases which would contribute to the accurate use of different types of data. In this regard, Xia maintained that analyzing and querying spatial data in this system allows the librarians, who use it, to manage spatial structures e.g. library space and study hall precisely and deeply [23]. Xia also employed GIS in visualizing the occupied space of the study hall at the central library of University of Arizona in which the study space is so vast in each floor [2]. To this end, the data related to the extent of use of the study hall at three levels of floor, section and hall were fed into GIS and the output maps were used in order to optimally design the library space.

The current study demonstrated that developing GIS as a tool for measuring and visualizing is quite easy. The only time-consuming part is collecting the data. Since the technical part of this system occurs in backstage, the users can just have a look at some user-friendly mediators. Implementing this system is also easy. Employing this system would enable the policy makers to focus more on real-world issues rather than to attempt to understand the data. Through providing precise information, GIS can help the libraries managers to make more informed decisions in order to improve the use of the study space [2], [30], [31], [36].

The current study was a step ahead in developing the application of GIS in measuring the extent of use of the libraries study space. GIS as a measurement technology has several advantages: 1) GIS can quite easily work with spatial databases which can store a set of data related to the daily performance of the library, 2) the power and flexibility of the GIS technology in utilizing the spatial data and managing the library space has facilitated the analysis of the library performance. Unfortunately, most researchers lose sight of the spatial characteristic of the data related to the study space and facilities. Is there any technology more appropriate than GIS for measuring the spatial location of the library facilities?

The findings are in line with those of Xia [2] and Mandel [30] in that GIS was shown to be an appropriate tool for visualizing the spatial data. The results for the analysis of the spatial data can be displayed on the map images. There is an old saying: "A map is worth more than one thousand words". People still believe that maps are limited to those which are daily read, like maps of the cities or physical maps with clear images of the surface of the earth. Indeed, anything with spatial nature can be depicted in the form of a map. This indicates how the chairs and desks inside the library can be depicted in the form of a spatial map.

When the study space and library facilities are depicted in the form of geographical maps the significance of GIS reveals. One asset of employing GIS in evaluating the library performance is that the maps and data are interactive. An individual who works with this system would be able to draw an image on the map by the cursor and simultaneously extract the relevant data from the database and can understand the potential of GIS development into an automatic system for managing the library in future. Hence, the idea of employing GIS in measuring and managing the library spaces and facilities was optimally confirmed in this study.

## VI. IMPLICATIONS AND APPLICATIONS (PRACTICAL SUGGESTIONS)

Considering the findings, a number of suggestions are presented in order to improve offering services in the central library of Tehran University:

The authorities and librarians of the central library of Tehran University are recommended to conduct a thorough and detailed examination of the obtained maps and information considering the occupied space and facilities (chairs and desks) in the current study and to take serious, pertinent actions for improving them taking the nature of the spaces into account. For instance, the occupancy coefficient of the desks and chairs in most studied halls indicated that those chairs and desks which were closer to the windows and outlets were more used for taking advantage of the natural light and scenery and charging the users' PCs, respectively. Hence, it is suggested that the stacks are not located by the windows and more chairs and desks are used in this space. Moreover, the number of electrical outlets should be increased around chairs and desks so that the users are provided with better access to these facilities.

Furthermore, since the occupancy coefficient of the chairs and desks of Abooreyhan hall was higher than those of the other halls, it seems that setting the chairs and desks which would avoid their direct, face-to-face contact is more welcome by the users. It is recommended to conduct a study and elicit the users' comments in order to support this issue. If this is true, the setting of the other halls should follow the same way in order to attract more number of users.

With regard to the library space design, it is suggested that a committee is formed for designing the interior space. The comments of the committee and the created information layers of the current study can be integrated in order to optimize the spaces and re-design them more appropriately based on the observations.

Considering the hours with higher occupancy coefficient of the chairs, it might be concluded that the users need the study space more in these hours and after them. Hence, the working hours of the halls should be adjusted.

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