Table 7. The Chi-square Test of Normal Distribution

Interval	Interval average	Frequency	Theoretical probability	Theoretical frequency np_i
0. 50~0. 40	0. 45	2	0. 0000	
0. 40~0. 30	0. 35	11	0. 0000	
0. 30~0. 20	0. 25	47	0. 0132	38. 966
0. 20~0. 10	0. 15	295	0. 1098	324. 129
0. 10~0. 00	0. 05	958	0. 3410	1006. 927
0. 00~-0. 10	-0. 05	1239	0. 3699	1091. 940
-0. 10~-0. 20	-0. 15	338	0. 1453	428. 925
-0. 20~-0. 30	-0. 25	59	0. 0207	61. 106
-0. 30~-0. 40	-0. 35	5	0. 0000	
-0. 40~-0. 50	-0. 45	3	0. 0000	
sum		2952	1. 0000	2952.000

Note: α =0. 01, s=6, l=2, S=0.0937, $\overline{Z}$ =-0.0075,S=0.0937, χ^2=56.508, $\chi^2_3(0.01) = 6.25$, $\chi^2 > \chi^2_3(0.01)$.

Table 8. Kolmogorov-Smirnov Test of NL Distribution (α =0. 01)

Map Serial	1		2		3	
Digitizer	x	y	x	y	x	y
1	0.262	0.264	0.225	0.309	0.291	0.243
2	0.207	0.283	0.275	0.335	0.264	0.254
3	0.266	0.258	0.252	0.287	0.281	0.206

tical test approach. Normal distribution is a normally acceptable distribution for describing error in GIS data. In this study, however, it was found that error of digitization is closer to another newly developed distribution — NL distribution under the experimental conditions. The functions of the NL distribution were also derived. The corresponding error models need to be redeveloped based on the NL distribution for handling error in measured GIS data.

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Spatial Structure of Accommodation Costs in the Madison Area

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Abstract

The spatial structure of accommodation costs in the Madison areas with respect to the direct distance from the University of Wisconsin-Madison campus was investigated using GIS and spreadsheet software. Major factors influencing the spatial variation of accommodation costs were discussed.

The spatial structure of accommodation costs indicated that the preferred and convenient locations for students were within two kilometres from the campus boundary. Factors such as proximity to social amenities, commercial centres, recreation parks and accessibility generally appeared to have significant impacts on the spatial structure of accommodation costs beyond two kilometres distance from the campus boundary.

I. INTRODUCTION

The University of Wisconsin-Madison has a student population of about 37,000 which comprises about 10% of international students from countries all over the world [1]. The high demand for student housing and accommodation each academic year has always exceeded supply. Existing hostels and dormitories and other university residential facilities located on campus can only accommodate about 6,800 students each academic year [2]. All of these residential facilities are normally fully occupied, and indeed, far from being adequate in accommodating the large student population. Fortunately, the proximity of UW-campus to the Madison City downtown areas has greatly alleviated the pressing accommodation needs of UW students. Rental services provided by many real estate agencies have made available a full range of off-campus accommodation and housing units within the vicinity of the campus to cater for the various needs of students. Various accommodation types ranging from dormitory room, efficiency to one-to more than three-bedroom apartment units are available for lease to students.

Affordability, location and safety are reckoned to be the foremost important factors that each student seeking accommodation invariably need to take into consideration before deciding on any particular unit [3]. One of the major concerns of a student prior to arriving at Madison was to secure a suitable and affordable accommodation. Most students, particularly those who have travelled half way round the globe to Madison have shared similar daunting and exasperating experience in their search for suitable accommodation. None of them feel assured, lest very much disheartened, on being informed by the University Housing Office that no accommodation could be arranged or guaranteed to new students due to limited space in existing housing facilities on campus. Being a newcomer to Madison, the search for a suitable and affordable accommodation proved to be overwhelming and frustrating, despite the compiled list of vacant accommodation units that was made available by the Campus Assistant Centre. In their eagerness to settle-in promptly, most new students would just grab the first available accommodation units that were seemingly within their budget limits.

Given the above scenario, it is therefore imperative for the relevant university authorities to provide adequate information and appropriate advisory services pertaining to the accommodation needs of newcomers. The main objective of the present study was to determine the spatial structure of off-campus accommodation costs in the Madison areas using GIS. Results from this preliminary study yield baseline information on the basic relationship between accommodation types and costs, and distance from the UW campus, which could be a useful basis for further in-depth studies.

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II. METHODOLOGY

Variables and Data Sets

In this study, the spatial structure of accommodation costs with respect to distance from the UW campus boundary was investigated. The problem definition comprises two major components, spatial variations of accommodation costs, and the UW-Madison Campus. The influence of accessibility and amenities such as proximity to major bus lines, business and commercial centres, on the spatial variation of accommodation costs within various city zones was also investigated.

The accommodation costs were reported in two categories: total monthly rent (Total Rent) and average monthly rent per room (Average Rent). Average monthly rent per room only applies to accommodation units with more than one bedroom. It was further assumed that the monthly rent for each room in any given apartment or house to be the same and hence the average rent per room was determined by dividing the total monthly rent by the number of rooms available in any housing unit. The rationale for this computation was that students might opt to live in a multiple room apartment or house by sharing out the total rent on a pro-rata basis. The total monthly rent by accommodation types was also relevant as a student with family may opt for a specific accommodation type. For instance, a family of three may opt for the whole of a two- or three-bedroom apartment unit. These values then provide a basis for comparison of accommodation costs among different accommodation types. Among accommodation types included in this study are room/efficiency, one-, two-, three- and more than three-bedroom. No distinction was made between townhouses and apartment units. Room and efficiency are accommodation units with shared and private kitchen combined with bathroom facilities respectively. Other accommodation units are differentiated based upon the number of bedrooms, all of which consist of a living room and kitchen and bathroom facilities.

The accommodation costs could further be defined as either inclusive or exclusive of utility costs. However, since the ratio of utilities costs to monthly rent is generally very small, and most of accommodation units were either fully or partially supplied with utilities such as heat and hot water supply, the influence of utilities costs on accommodation costs was rather minimal and insignificant. All utility costs were therefore omitted in the analysis.

As the focus of this study was on UW-Madison students, the spatial variation of accommodation costs was computed based on the direct (shortest) distance from a given location to any point on the UW campus boundary. Distances were computed based on the following two factors: (a) the geo-coded locations of accommodation units, and (b) the shortest distance to any part of the UW-Madison campus boundary. The geo-coded locations of all accommodation units were derived based on matching their street addresses to the Madison City street map data file. The location of UW-Madison campus was defined by its polygonal boundary, and was used for the computation of the shortest distance from any given location.

Sources of information used in the present study include: (a) City street map of Madison converted from TIGER Files were obtained from Land Information and Computer Graphics Facility (LICGF), UW-Madison, and (b) Data on accommodation units was obtained from the compiled list provided by the Campus Assistant Centre and advertisements posted in *'Start Renting'* Info magazine.

Implementation

The overall implementation process was performed on ArcView (GIS) and Microsoft EXCEL (spreadsheet) software platforms as shown in Figure 1. A database with pertinent information of accommodation units was first created and stored as a spreadsheet format file using Microsoft EXCEL. The data was then imported directly into ArcView for subsequent GIS analyses. A total of 508 accommodation locations were collected and used in this study. Each of these was then geo-coded onto the street map of Madison. (Figure 2).

Distance Calculation

The nearest distance of each available accommodation unit to the campus boundary was computed using ArcView. In ArcView, the *Select Feature by Theme* [4] function allows user defined distance intervals from a given feature within a theme (i.e. the campus boundary) to be specified. A series of incremental distances (50 metres interval for distance within 4 kilometres and 100 metres intervals for distance beyond 4 kilometres from the UW campus) were then specified and the corresponding point features (i.e. accommodation units) that fell within specified distance interval were identified in turn. Such distance intervals were used as the equivalent of the commonly used distance measure of 'block'. These data were then selected and exported as spreadsheet format files for further analyses using Microsoft EXCEL. Scatter plots of spatial variations of accommodation costs with respect to distance from the campus boundary were then generated with Microsoft EXCEL.

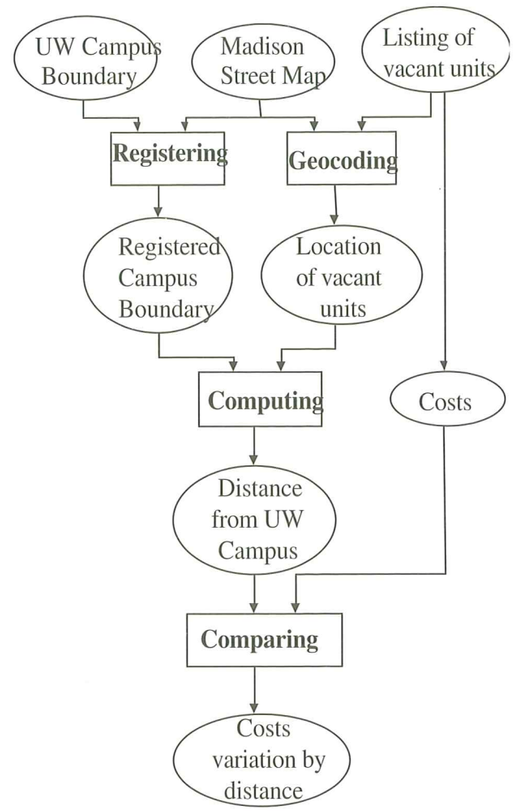

Figure 1. The implementation process.

III. RESULTS AND DISCUSSION

The spatial distribution of various accommodation types was as shown in Figure 2. Based on this data, a majority of the accommodation units were distributed within a distance of ten kilometres from the UW-Madison campus boundary. Generally, a scattered distribution pattern with more and denser clusters of accommodation units was observed, particularly in areas close to the campus, and within the Madison City downtown areas. Several smaller clusters were also observed further away from the campus which were believed to be associated with proximity to commercial and business centres and other social amenities available in these areas.

Accommodation Types

Most of the efficiency/room units were found located within the downtown areas and near the UW-Madison campus (Figure 2). Presumably, there was a comparatively higher demand for such efficiency/room units by students due to their affordability and convenient locations. Both of one- and two bedroom units had shown quite similar distribution patterns, with clusters observed in the downtown area, areas near the campus, and at areas that were further away from the campus but close to commercial complexes and other social amenities. In general, one- and two-bedroom units appeared to be more preferred and popular choices among both students and working population. The three-bedroom units were observed to be rather widely scattered with few clusters observed. It was believed that such units were often needed by people with larger families rather than students. However, most of accommodation units with more than three bedrooms were located near the campus, indicating preference of some students to share out such larger units for reasons of convenience and affordability.

Accommodation Costs

The spatial variation of accommodation costs for all types combined was shown in Figure 3. Both the total monthly rent and average monthly rent per room showed a very similar spatial variation pattern. A significant range of variability in accommodation costs was observed along the whole span of distance within the study area, particularly for units located closer to the campus. There was a noticeable declining trend for accommodation costs, as well as clusters of concentration were observed within a distance of two kilometres from the campus. Such clusters of accommodation units within two kilometers from campus should reflect the general high preference of students for convenient locations near the campus. A distance of two kilometers could henceforth be recognized as the buffer limit of reasonably convenient location from the campus.

The slightly higher accommodation costs associated with units located near the campus was anticipated since demands for such accommodation units were always comparatively higher. The high variability of accommodation costs observed could in part be attributed to the combination of different types of accommodation units, and also attributed to variation of accommodation costs associated with provision of additional furnishings, amenities and special features. Exclusiveness and prestige associated with certain accommodation units and certain neighborhood should therefore be reflected in the upper accommodation cost ranges.

Beyond a distance of two kilometers from the campus,

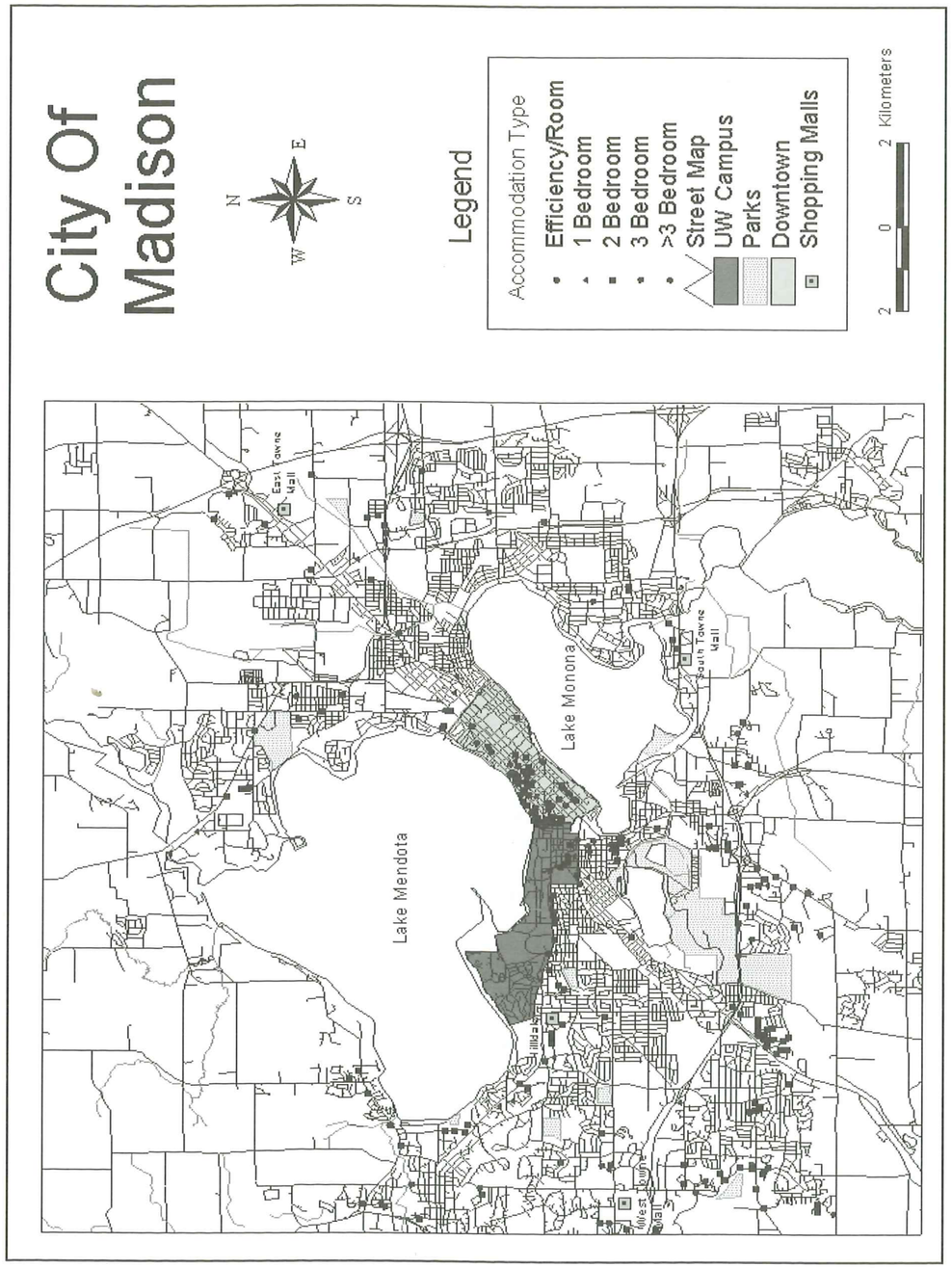

Figure 2. The spatial distribution of various accommodation types, and location of UW campus, Madison Downtown and points of interest.

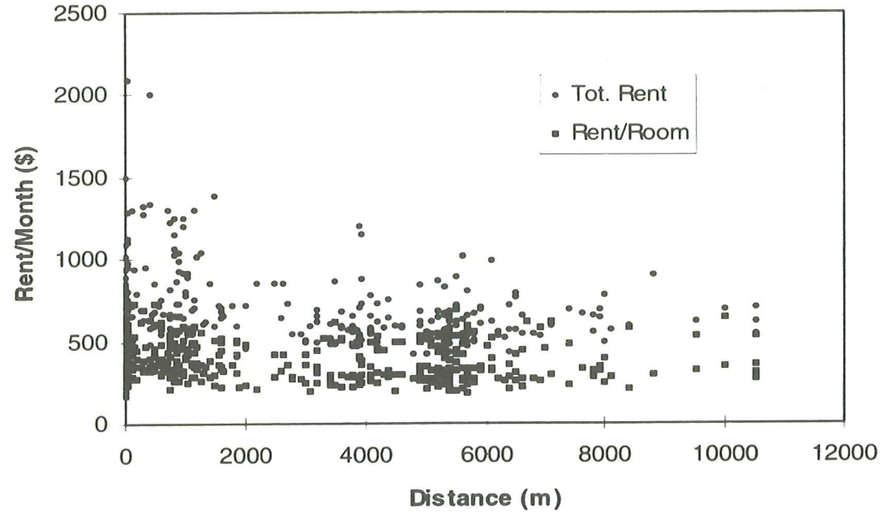

Figure 3. The spatial variation of accommodation costs for all accommodation types combined.

there was no distinct declining trend but clusters of concentration of units were again observed at distance between three and four kilometers and between five and six kilometers from the campus respectively. Such clusters were believed to be associated with proximity to various points of interest such as business and commercial centers and social amenities (for instance, the Hilldale, East, West and South Town Malls), and various recreational parks (Figure 2).

It could be observed that the location of UW-Madison campus no longer exert any significant influence on the spatial structure of accommodation costs beyond a distance of two kilometers. In other words, a distance of more than two kilometers from the campus boundary was no longer considered convenient locations for most students. Indeed, it could be observed that most clusters appeared to span over a distance of about two kilometers. This observation concurred with earlier contention that the general confine of spatially convenient location appeared to lie within a buffer distance of two kilometers from any given point of interest.

The spatial structure of accommodation costs was further investigated by accommodation types (Figure 4). In an attempt to elucidate the pattern of spatial variation of accommodation costs with respect to distance from the campus, we computed the mean accommodation cost for various distance intervals. A noticeable declining trend in the average monthly rent for all accommodation types, except for the room/efficiency and the one-bedroom units, was observed within a distance of two kilometers from the campus. This could be attributed to a consistently high preference and demand for small accommodation units such as efficiency and one-bedroom units by students that were at convenient location of the campus. No such declining trend of the mean accommodation costs was observed for all accommodation types beyond two kilometers but they remained rather constant within the study area. In fact, the average monthly rent of one bedroom units appeared to increase slightly with increasing distance from the campus. Similar pattern of clusters associated with proximity to commercial centers and social amenities were again observed for all types of accommodation units. Significant variability in accommodation costs for all accommodation types over the whole range of distances within the study area concurred with earlier observation and could be attributed to the inclusion of accommodation units which were more luxurious and exclusive in term of furnishings and special features. For instance, accommodation units which were located within prime or exclusive residential areas should command comparatively higher monthly rents.

In a study of this nature, it was recognized that the accuracy of rent or accommodation costs associated with any given accommodation location was most critical in order to yield a more realistic picture on the spatial structure of accommodation costs in the Madison area. Consequently, one major limitation that should be highlighted was the data set used in this study. This data set was based entirely on

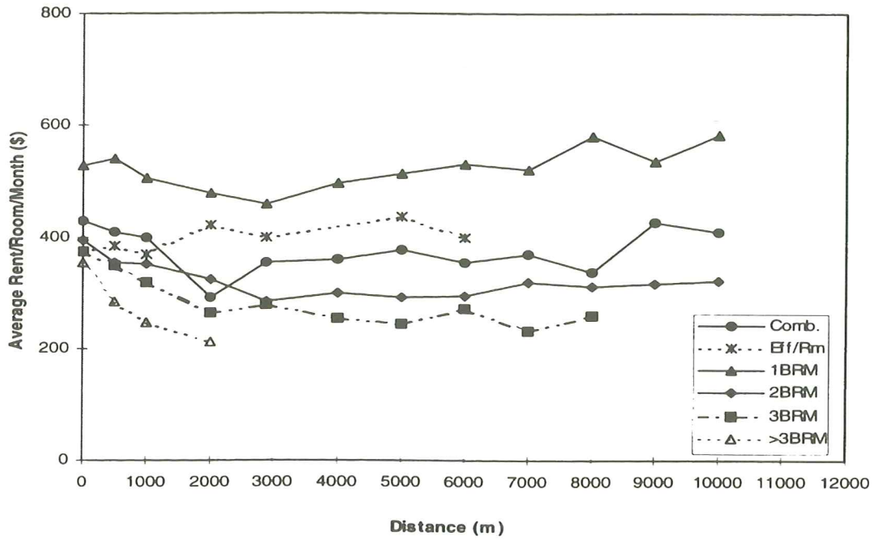

Figure 4. The spatial variation of average accommodation cost by accommodation types.

advertisements and compiled list of VACANT accommodation units. Information on occupied accommodation units within the study area were not available and therefore not used in this study. In most cases, explicit rent values associated with any given accommodation units were not available, instead implicit values such as 'starting from' rent or only a low-to-high rent range were given. Such rent values might not reflect adequately and representatively the actual rent or the actual accommodation cost associated with that particular location. Factors such as prime neighborhood locations, types of furnishings, sizes, utilities, amenities or special features might affect the eventual accommodation costs significantly.

For any future in-depth study, it is therefore highly desirable to collect comprehensive information with break-down on the actual rent by rooms and/or by accommodation types associated with any given location. One feasible and prudent approach envisaged is to solicit the co-operation of all real estate agencies in Madison to provide information on all the apartment and housing units that they are currently undertaking. These information should provide a much higher accuracy with respect to rent and distance, and therefore should yield a much more realistic picture pertaining to the spatial structure of accommodation costs with respect to the distance from the UW-Madison campus.

Based on the preliminary findings of this study, future study pertaining to students' accommodation needs should preferentially focus on areas within a distance of two kilometers from the campus boundary. For the benefits of all students, particularly new students, it is highly desirable of setting up a comprehensive information management system that provides effective storage and retrieval of up-to-date accommodation information. The present database available in the Campus Assistance Center can be a good starting point, for the eventual setting up of an accommodation information management system. For effective and convenient dissemination of such information to all individuals on campus, such system needs to be implemented on-line over the campus-wide network or even on the World Wide Web site for easy access. It is envisaged that by coupling the functionality of GIS [5] to the versatility of existing database management software would go a long way in disseminating up-to-date accommodation information to the campus community effectively and efficiently and to facilitate the search for suitable accommodation that meet individual needs and preferences.

V. CONCLUSION

The spatial structure of accommodation costs indicated that the preferred and convenient accommodation locations for students lied within a distance of two kilometers from the campus boundary. Generally, there was a slight declining trend in accommodation costs within a distance of two kilometers from the campus. Beyond two kilometers from the campus boundary, factors such as proximity to social amenities, commercial centers, recreation parks as well as accessibility, generally appeared to have substantial impacts on the spatial structure of accommodation costs and the spatial distribution of accommodation units.

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