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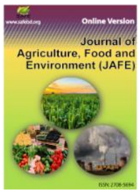

*Research Article*

# Perception-based planning approach for infrastructural development: Sylhet Agricultural University, Bangladesh

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**A B S T R A C T**

Infrastructure is required for proper education and research in a university. Sylhet Agricultural University is a new varsity blooming in the last decade which was upgraded from a college. After establishment, some buildings have been constructed and some are still under construction. Therefore, a plan is proposed to properly use the remaining free lands to construct new infrastructures through this research work after systematically studying the land and facilities. At first, an engineering survey was conducted to prepare paper-based and computerized 2D maps indicating existing infrastructures. Proposed sites for future infrastructures were also identified and justified by a study involving different groups within the university community. Based on the perceptions gathered, the maps were finalized to show the locations of buildings suggested by most interviewees. Afterward, buildings were constructed on the campus, some of which match the locations suggested by this study. Thus, for further construction, this map could be an important guideline.

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## INTRODUCTION

University campuses serve as dynamic hubs of education, innovation, and community engagement, requiring careful infrastructural planning to accommodate diverse needs and aspirations (Youtie & Shapira, 2008). In recent years, a paradigm shift towards perception-based planning has emerged as a strategic approach to address the multifaceted challenges of developing and revitalizing university campuses (Moganadas *et al.*, 2013). Unlike traditional planning methods solely driven by functional requirements and architectural standards, perception-based planning strongly emphasizes understanding the subjective experiences, preferences, and behaviors of stakeholders within the campus environment (Abd Razak *et al.*, 2011; Baedeker *et al.*, 2020). This introduction aims to outline the key principles and benefits of perception-based planning within the context of infrastructural development for the campus of Sylhet Agricultural University (SAU), Bangladesh. By integrating insights from psychology, sociology, urban design, and environmental psychology, perception-based planning offers a holistic framework for creating campus environments that foster creativity, well-being, and a sense of belonging among students, faculty, staff, and visitors (Norman, 2013; Thomas, 2021). At its core, perception-based planning acknowledges that the built environment influences human behavior, emotions, and cognitive processes. It recognizes the importance of factors such as spatial layout, architectural aesthetics, natural surroundings, accessibility, and social interactions in shaping individuals' perceptions and experiences within the campus (Anis *et al.*, 2018; Putri *et al.*, 2020). By adopting a user-centered approach, planners and architects can gain valuable insights into how different elements of the campus environment impact the quality of life and academic performance of its inhabitants (Lucchi and Delera, 2020). Moreover, perception-based planning encourages interdisciplinary collaboration and stakeholder engagement throughout the planning and design process. By involving diverse voices and perspectives, including students, faculty, administrators, and local communities, planners can gain a comprehensive understanding of the unique needs and aspirations of the campus community (Abd Razak *et al.*, 2011). Through case studies and best practices, we will illustrate how universities around the world are embracing perception-based planning to create vibrant, resilient, and human-centered campus environments that inspire learning, creativity, and innovation.

Infrastructural developments are the fundamental and usually permanent framework that supports a superstructure and is supported by a substructure. The permanent foundational capital investment of a university includes academic, administrative, telecommunications, transportation, utilities, waste removal infrastructure, among others. (Coulson and Roberts, 2011). For a proper learning environment, an infrastructural development plan is essential for a university (Coulson and Roberts, 2011). It helps in making decisions regarding how the facilities and grounds of a campus can be intellectually utilized for both teaching and research purposes (Alshuwaikhat and Abubakar, 2008). Infrastructural development is impossible without proper planning because that can play a vital role in the development of a campus environment. Hence, this study was undertaken in 2015 to propose a development plan for SAU based on a needs-driven assessment of future development requirements including the amount of land that needs to be zoned for particular purposes.

The SAU had only the existing buildings of SGVC in 2006, and later on, some other buildings were being established as an ongoing process. There are six faculties in the university. During 2015 for the faculties, 3 buildings existed and 3 were under construction where 1 constructed and 1 instruction building was allocated for the Faculty of Veterinary and Animal Sciences, and no full building was permanently allocated for the Faculty of Biotechnology and Genetic Engineering (Figure 2). There were 4 student dormitories (halls) for the gents and one building under construction. Based on the proportion of female students one dormitory (hall) and one extension building were allocated. Other important infrastructure included buildings for the library, mosque, cafeteria, veterinary clinic, staff quarter, bus stand, guest house, old library, auditorium, gymnasium, security shed, teachers' dormitories, and the Vice-Chancellor's (VC) bungalow. The other buildings that were under construction in 2015 were for the 3 faculties, a monument in memory of the mother language martyrs (Shaheed Minar), a veterinary clinic, a guest house, etc. Due to the construction of those ongoing buildings vacant lands were being occupied and in some cases, ponds and small lakes were filled up and hills were cut to obtain places for those under-construction buildings. Moreover, it is assumed that in the future, many other buildings need to be constructed. To properly use the rest of the vacant land this study was undertaken to propose an infrastructural development based on a perception of its dwellers from a questionnaire-based survey. Notably, the campus possesses several small hills, some of which were cut for different development purposes. One of the purposes of this study was to suggest the best use of the hilly lands without cutting those hills. It was supposed that the output of the current study would support the future construction plan of SAU through the utilization of its valuable land properly as well as generate wider benefits for both campus and community considering all environmental effects.

In conclusion, perception-based planning represents a transformative approach to infrastructural development on university campuses, recognizing the intrinsic connection between the built environment and human perception. By prioritizing the well-being and experiences of campus inhabitants, this approach empowers planners, architects, and stakeholders to design campus environments that reflect the values, aspirations, and identity of the academic community. As universities continue to evolve in response to changing societal needs and technological advancements, perception-based planning offers a robust framework for creating campus environments that nurture learning, collaboration, and personal growth.

## MATERIALS AND METHODS

### Location of the study area

In 2006, SAU was established around 3.5 km northeast of the center of the district town of Sylhet (Figure 1). This was upgraded from Sylhet Government Veterinary College (SGVC) which was established in 1995 (www.sau.ac.bd) at the same place as the "School of Life Sciences" under the Shahjalal University of Science and Technology, Sylhet, Bangladesh. During its establishment, the SAU campus area was around 50 acres (Hossain *et al.*, 2016). There is also a possibility of an extension of the land area for this university. By 2015 around half of its total land was used up by infrastructure development (Hossain *et al.*, 2016). At the beginning of academic activities, its total population was near about 700 with a few numbers of infrastructures, but during 2015 the total population became almost 3,500 (Hossain *et al.*, 2016).

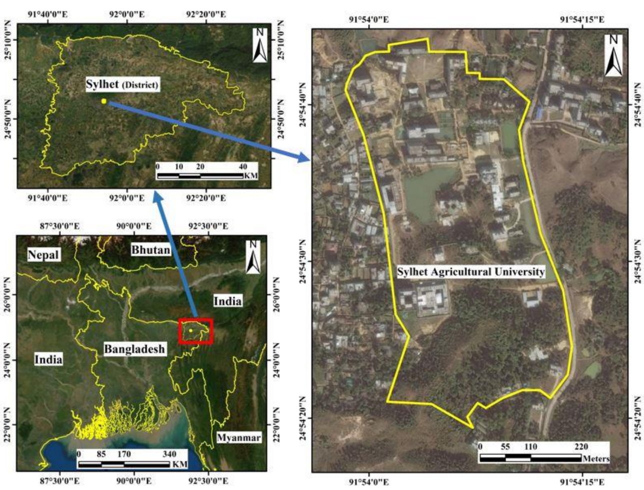


**Figure 1:** The location map of SAU

For proper planning of an infrastructural development in a university firstly it is necessary to prepare a map of existing buildings and facilities through any form of engineering survey. Afterward, it is necessary to find out the requirements of its dwellers or users through a perception survey before finalizing the locations of required new buildings. Therefore, in this study an initial map was prepared by the field survey; thus, preliminarily some new buildings were proposed in the map. Afterward, a questionnaire-based survey was conducted along with the visualization of the preliminary proposed map. Finally, based on the analysis of perception the locations of new buildings were finalized (Figure 2). All of these processes are briefly described in the following subsections.

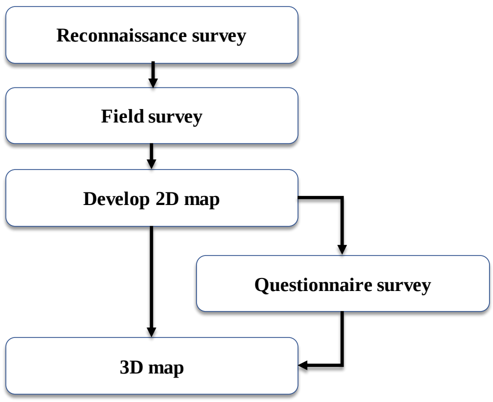


**Figure 2:** Flowchart of the mapping for infrastructure planning development.

## Reconnaissance Survey

An extensive study of the entire target area which will be used for infrastructure development is called a reconnaissance survey. It is the first step in the surveying process (Schofield and Breach, 2007). It is very important because it makes the engineering work economical and ensures the accuracy of specifications as it helps to decide the proper techniques and instrumentation for the construction work (Schofield and Breach, 2007). It also helps to eliminate those sites that are impractical for the desired construction as well as to identify more promising sites. Therefore, in this study, a detailed reconnaissance survey was conducted to find out the existing conditions of the infrastructures and facilities of the study area which also helped in the systematic design of the work steps for the whole study.

## Engineering Survey

The two-month engineering investigation was initially carried out to determine the most effective means to carry out the operation. Two distinct survey methods, chain and contouring survey were used throughout the entire procedure. All details like buildings, roads, ponds, canals, lakes, drains, culverts, etc. were taken into consideration during this survey.

### Chain survey

In chain surveying, the process of measuring the horizontal linear distances between the desired sites using a chain and tape is known as "chaining." It helps to make a plan for the area to be surveyed (Duggal, 2013). It's a basic kind of survey where the length is determined by creating many triangles out of the studied region (Aziz and Shahjahan, 1965; Hossain *et al.*, 2016). Some suitable stations were selected on the ground and indicated by setting some ranging rods on the ground. The stations were placed on the study area in strategic locations to measure the distances between a number of significant artifacts. The perpendicular distance called offsets of various objects in the field from the chain line were measured and recorded in a field book. Based on these recorded data the whole area was plotted on a drawing sheet to a suitable scale (Hossain *et al.*, 2016). Later on, a 3D map was also created based on this paper-based map and recorded data. To perform this survey chain, tape, ranging rods, arrows, optical square and offset staff were used (Hossain *et al.*, 2016).

### Contouring

Contours are imaginary lines joining points of equal altitudes upon the earth's surface concerning a fixed datum (Uren and Price, 1994). The procedure used to create a contour map is referred to as contouring. Utilizing a contour map facilitated the prediction of terrain features such as ridges, valleys, depressions, etc. Two contouring methods were employed: one referred to as the direct method and the other as the indirect method (Aziz and Shahjahan, 1965). In this work, the direct method was used. At first one contour level is defined as a baseline and based on that the elevations of the whole area including the buildings were measured physically. Those positions on the map were plotted by plane tabling. Finally, those elevations were visually verified based on the Google Earth Pro map.

## Mapping

At first, a paper-based primary map was prepared just after the chain survey. Afterward, a 2D digital map was prepared by using AutoCAD software. This map includes the existing buildings and other types of structure locations. Later on, the locations of the proposed buildings were added primarily. For a proper understanding of the current locations of the buildings as well as the locations of required buildings proposed by the interviewee, a preliminary 3D map was prepared based on the 2D map. The 3D map was prepared by using Sketch-Up software. After the survey work, the preliminary 3D map was modified and finalized based on the perception information gained from the survey.

## Questionnaire-based survey

A questionnaire-based survey was conducted from June 2015 to December 2015 to know the desires and comments on the preliminary maps from different levels of the users of the infrastructures like Dean of all faculties, Chairman of several departments, engineers, administrative officers, and students of both sexes from different faculties. For that purpose, a questionnaire was prepared emphasizing questions on the requirements of new buildings. Assessment of priority for future building construction was also conducted based on their opinions. All the data from all completed questionnaires were tabulated and analyzed accordingly.

To prepare a priority index from Table 1 continuous scale values were set. According to the higher to lower priorities those were categorized as 1st, 2nd, 3rd, and no priority designating priority index values of 3, 2, 1, and 0, respectively. After that, the priority index was calculated by the following formula (Miah, 1993):

$$I = \sum \frac{S_i f_i}{N}, \quad \text{……………………………………….(1)}$$

where,

$I$ = Priority index ($0 \leq I \leq 3$)

$Si$ = Scale value at $i^{th}$ priority

$fi$ = Frequency of $i^{th}$ priority

$N$ = Total number of observations

## Formation of Model

One significant application of mathematical modeling in building plan design is optimization. Architects and engineers often use mathematical models to optimize various aspects of a building's design, such as structural integrity, cost-effectiveness, energy efficiency, and aesthetic appeal. Here's how mathematical modeling can be applied in building plan design (Adams, 2019; Smith and Johnson, 2020; Thompson *et al.*, 2018):

### *Structural Analysis*

Engineers use mathematical models to analyze the structural integrity of a building design. Finite Element Analysis (FEA) is a common technique where complex structures are broken down into smaller, more manageable elements, and mathematical equations are applied to simulate how these elements behave under various conditions like loads, stresses, and strains. By optimizing the design using FEA, engineers can ensure that the structure can withstand expected loads while minimizing material usage and cost.

### *Energy Efficiency*

Mathematical models can be employed to optimize a building's energy efficiency. This involves simulating the building's thermal performance using computational fluid dynamics (CFD) or other techniques. By analyzing factors such as insulation, window placement, and HVAC system design, architects and engineers can determine the most energy-efficient design for a building.

### *Cost Optimization*

Mathematical optimization models can help minimize construction costs while meeting design requirements and constraints. This involves formulating an optimization problem with cost-related objectives and constraints such as material costs, labor costs, and project timelines. Techniques such as linear programming, integer programming, and genetic algorithms can be employed to find the most cost-effective design solution.

### *Space Utilization and Layout Optimization*

Mathematical models can aid in optimizing the layout and utilization of space within a building. This includes determining the optimal arrangement of rooms, corridors, and other architectural elements to maximize functionality and efficiency. Optimization algorithms can consider factors such as traffic flow, accessibility, and spatial requirements to generate an optimal layout.

### *Sustainability Analysis*

Mathematical models can evaluate the environmental impact of a building design and identify opportunities for sustainability improvements. Life Cycle Assessment (LCA) is a common approach where the environmental impacts of a building design are assessed throughout its entire life cycle, from material extraction to construction, demolition, and operation. By quantifying factors such as carbon emissions, energy consumption, and resource usage, architects and engineers can make informed decisions to minimize environmental footprint.

### *Risk Management*

Mathematical models can be used to assess and mitigate the risks associated with building design and construction. For example, probabilistic modeling techniques can analyze the likelihood and potential consequences of various risks such as structural failures, cost overruns, and schedule delays. By incorporating risk analysis into the design process, stakeholders can make more informed decisions to minimize the likelihood and impact of adverse events.

Overall, mathematical modeling plays a crucial role in optimizing building design across various dimensions, including structural integrity, energy efficiency, cost-effectiveness, sustainability, and risk management. By leveraging mathematical techniques and computational tools, architects and engineers can develop innovative and high-performance building designs that meet the needs of stakeholders while minimizing negative impacts on the society and environment.

## Mathematical model based on the given perception-based planning approach

To establish a perception-based planning approach for the infrastructure development of a university campus, we have to take the following mathematical model equations by choosing some parameters (Neetesh *et al.*, 2020; Georgia and George, 2013; Madeline *et al.*, 2021).

## Campus area growth model

The growth of the campus area over time can be modeled using various functions, such as linear or exponential growth, depending on factors like construction pace, available land, and development plans: which is given by the following equation,

$$A(t) = A_0 + \int_0^t \beta I(\tau) d\tau, \quad (2)$$

where $A(t)$ implies the area of the campus at time $t$, $A_0$ is the initial campus area, $\beta$ is the efficiency factor converting investment into the campus area and $I(t)$ implies the investment in infrastructure at the time $t$.

### Student capacity model Student growth model

The student capacity of the campus should ideally expand in tandem with the development of the campus area and infrastructure. This can be modeled as a function of the area and efficiency of space utilization,

$$S(t) = \gamma A(t), \quad (3)$$

where $S(t)$ implies the student capacity of the campus at any time $t$ and $\gamma$ implies the efficiency factor of converting the campus area into student capacity.

Now, the growth of the student population over time can be modeled using an exponential or logistic growth function, taking into account factors such as enrollment rates and population dynamics,

$$P(t) = P_0 \, e^{rt}, \quad (4)$$

where $P(t)$ implies the total student population at the time $t$ and $P_0$ is the initial student population and r is the growth rate.

### Academic Program Growth Model

The number of academic courses offered should grow to accommodate the needs of the expanding student population and to enhance the academic reputation of the university given by the model equation,

$$C(t) = C_0 + \alpha P(t), \quad (5)$$

where $C(t)$ implies the number of academic courses offered at the time $t$, $C_0$ is the initial number of academic courses and $\alpha$ is the proportionality constant relating population growth to course expansion.

### Investment in Infrastructure Model

The investment in infrastructure should be proportional to the growth objectives of the university and the perceived needs of the community given by the following model,

$$I(t) = I_0 + \delta R(t), \quad (6)$$

where $I(t)$ indicates the investment in infrastructure at time $t$, $I_0$ implies the initial investment in infrastructure and $\delta$ implies the proportional constant relating reputation to investment.

### Reputation Model

The reputation of the proposed university plays a significant role in attracting students, faculty, and funding. It can be influenced by several factors, including academic quality, research output, and alumni success which are associated with the following model equation,

$$R(t) = R_0 + \eta C(t), \quad (7)$$

where $R(t)$ indicates the Reputation score of the university at time $t$, $R_0$ is the Initial reputation score and $\eta$ is a proportionality constant relating course offerings to reputation.

### Budget constraint

The budget allocated for infrastructural development should be within certain limits and should be balanced against other financial requirements of the university which is given by the following relation,

$B(t) \leq$ MaxBudget.

Using these models and constraints, university planners can simulate different scenarios, optimize budget allocations, and prioritize infrastructural projects to meet the evolving needs of the university community while staying within budgetary constraints. This mathematical framework provides a structured approach to perception-based planning for university infrastructure development. However, it's important to note that real-world implementation would require more detailed data, refinement of models, and consideration of additional factors such as land availability, environmental regulations, and socio-economic impacts.

## RESULTS AND DISCUSSION

In this section, we obtain some results and graphical portraiture using the above-mentioned model equations (1-7). Based on the suggestions and requirements from the questionnaire survey result a 3D map was proposed, which is shown in Figure 3 as a 2D map. The map was georeferenced which shows the existing buildings as well as under construction buildings during the period of the survey. Moreover, the proposed locations for new infrastructure requirements are also shown on the map by some alphabets in the upper case which are identified in the last column of Table 1.

After proposing this map some buildings were constructed and some are also being constructed currently. During the construction of those buildings, some were constructed in the same locations as proposed in this map.

In Table 1, the percentages of the total 275 respondents regarding their opinions on the construction of proposed buildings are shown. The percentage of the priority categories is also shown in this table. Out of the proposed locations, the percentage of agreed respondents for each of the proposed locations is also shown in Table 1. By using this formula the indexes are summarized as presented in Table 2.

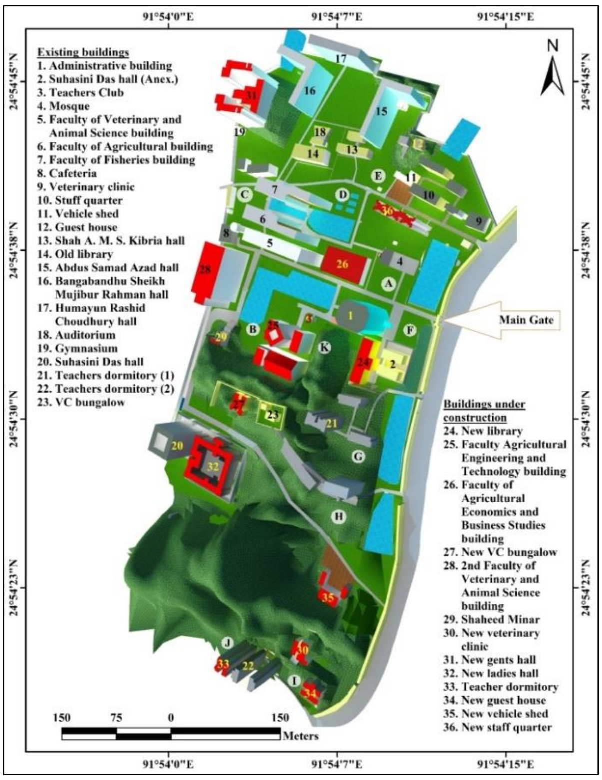


**Figure 3:** The prepared 3D map showing the existing, under construction and proposed infrastructures.

**Table 1.** Distribution of respondents by participants on different proposed structures.

| Proposed structure | Requirement statement | | Percentage of priority statement categories | | | Agreed locations on maps (refer to Fig. 3) with percentage |
|---|---|---|---|---|---|---|
| | Yes | No | Immediate | Soon | Later | |
| 1) 2nd Administrative building | 51% | 49% | 17% | 33% | 50% | **(F)** 42% **(A)** 58% |
| 2) Auditorium | 100% | 0% | 70% | 28% | 2% | **(B)** 100% |
| 3) TSC | 95% | 5% | 71% | 29% | 0% | **(8)** 100% |
| 4) Building for the Faculty of Biotechnology and Genetic Engineering | 100% | 0% | 75% | 21% | 4% | **(C)** 17% **(D)** 83% |
| 5) Gymnasium | 81% | 19% | 47% | 52% | 1% | **(18)** 100% |
| 6) Health care center | 100% | 0% | 49% | 40% | 11% | **(2)** 100% |
| 7) Planning and Engineering section | 35% | 65% | 0% | 43% | 57% | **(1)** 85% **(19)** 15% |
| 8) Central laboratories | 75% | 25% | 14% | 73% | 13% | **(14)** 100% |
| 9) Teachers quarter | 74% | 26% | 20% | 68% | 12% | **(I/J)** 100% |
| 10) Officer's quarter | 26% | 74% | 21% | 28% | 51% | **(G/H)** 100% |
| 11) Extended faculty building | 85% | 15% | 10% | 51% | 39% | **(C)** 77% **(D)** 23% |
| 12) Teachers club | 75% | 25% | 26% | 58% | 16% | **(8)** 100% |

**Table 2.** Dweller's opinion of the proposed building.

| Priority | Frequency of responses for proposed building | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **AB** | **Au** | **TSC** | **BFB** | **Gym** | **HCC** | **PES** | **CL** | **TQ** | **OQ** | **EFB** | **TC** |
| 1 | 70 | 5 | 0 | 12 | 56 | 28 | 55 | 28 | 24 | 36 | 93 | 61 |
| 2 | 45 | 79 | 77 | 58 | 116 | 112 | 42 | 151 | 140 | 19 | 117 | 119 |
| 3 | 25 | 191 | 184 | 205 | 51 | 135 | 0 | 28 | 42 | 14 | 23 | 53 |
| 0 | 135 | 0 | 14 | 0 | 52 | 0 | 178 | 68 | 69 | 206 | 42 | 42 |
| **Total** | **275** | **275** | **275** | **275** | **275** | **275** | **275** | **275** | **275** | **275** | **275** | **275** |

**Note:** AB- 2nd Administrative building, Au- Auditorium, TSC, BFB-Bio tech. Building, Gym-Gymnasium, HCC-Health Care Center, PES-Planning and Engineering Section, CL-Central Laboratory, TQ-Teachers Quarter, OQ-Officer's Quarter, EFB-Extended Faculty Building, and TC-Teachers club.

**Table 3.** Priority index for the proposed building.

| List of proposed building | Priority Index | Ranking in order of priority |
|---|---|---|
| Biotechnology faculty building | 2.70 | I |
| Auditorium | 2.67 | II |
| Teacher-Student Centre (TSC) | 2.56 | III |
| Health Care Center | 2.39 | IV |
| Teachers club | 1.66 | V |
| Gymnasium | 1.60 | VI |
| Teachers Quarter | 1.56 | VII |
| Extended Faculty Building | 1.44 | VIII |
| 2nd Administrative building | 0.85 | IX |
| Central Laboratory | 0.77 | X |
| Planning and Engineering Section | 0.50 | XI |
| Officer's Quarter | 0.42 | XII |

From the derived priority index of the proposed buildings, it is obvious that the Faculty of Biotechnology and Genetic Engineering (BGE) building is in the 1st ranking in the order of priority. During 2015-2016, there were no full buildings for BEG; thus the students of BEG had no lab facilities because they had no faculty building. Thus, it can be inferred that BEG was suggested to be built urgently by most of the respondents. From the perception of the interviewee as well as the engineering point of view, position "D" (Figure 3) was selected for the BGE building. The upper case alphabets on the map demonstrate the proposed locations of suggested infrastructures in Figure 3 and Table 1.

The existing auditorium was inadequate for accommodating a large number of participants. It is situated centrally among four genet's halls beside the old library. During cultural or educational programs, a significant number of students are unable to enter the auditorium. At the time of the cultural program, it caused noise pollution, greatly disrupting the concentration of students studying in the Genets Hall. Therefore, a new Auditorium with 1,000 seats in position "C" was suggested for construction as early as possible. That's why it got the second priority for construction.

Though the existing dormitories and quarters are not enough to accommodate all of the officers in SAU, the number is not so small. Supposedly, for this reason, the officers' quarter got less priority in the respondents' demands.

In the third position of ranking the order of priority is the Teacher-student center (TSC). The TSC aims to enhance campus community life, complementing the formal academic program of the university. It serves as a venue for campus organizations to conduct meetings, events, lectures, and art exhibitions. Discussion sessions, publication of journals and bulletins, and hosting competitions contribute to a diverse array of cultural and social events at the university. Therefore, The TSC was selected as a third priority.

## CONCLUSION

In this study, a land use plan for future infrastructure development in SAU is proposed. At first, some survey method was used to know the existing condition of the campus and from the questionnaire survey it was tried to understand the opinion of the campus population (students, teachers, administrative officers). By using the priority setting equation it is found that BGE faculty building is to be constructed immediately. Then a new auditorium of 1000 seats are to be constructed, and TSC got the third priority. Based on the priority other eight buildings got priorities. If these buildings are constructed according to the priority list and according to the proposed location, the vacant and unused places will be properly utilized. This will not only increase the beautification of the university campus but also the proper utilization of unused places. Thus, this map is supposed to support the future infrastructure development of SAU.

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