

# УПРАВЛІННЯ В ОРГАНІЗАЦІЙНИХ СИСТЕМАХ

## MANAGEMENT IN ORGANIZATIONAL SYSTEMS

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### FUZZY LOGIC IN DORMITORY ACCOMMODATION RECOMMENDATION SYSTEMS: ACCOUNTING FOR UNCERTAINTY AND LINGUISTIC STUDENT PREFERENCES

The problem of student dormitory room allocation is considered as a multi-criteria decision-making task under uncertainty. The relevance of the study is driven by the need to improve the quality of accommodation processes through intelligent recommendation approaches that account for individual student preferences, rather than relying on simple filtering mechanisms. The aim of the paper is to develop a recommendation model that evaluates the suitability of dormitory rooms based on both quantitative characteristics and subjective user preferences. To achieve this goal, a fuzzy logic approach is applied to model the linguistic nature of user requirements and to handle uncertainty in decision-making. The proposed model calculates partial compatibility scores for multiple criteria, including price, distance, comfort, noise level, and social compatibility, and aggregates them into an overall suitability measure for each student–room pair. The effectiveness of the approach is evaluated by comparing it with the Simple Additive Weighting method, used as a baseline. The results show that the fuzzy logic-based approach provides more differentiated and flexible recommendations, better representing diverse student preferences and improving the quality of ranking alternatives. The analysis of score distributions shows that the fuzzy logic approach yields a smoother, more continuous range of compatibility values, whereas the additive weighting method tends to produce clustered scores, reducing the ability to distinguish between alternatives. The proposed method can be used as a decision-support tool in dormitory management systems to enhance allocation efficiency and user satisfaction.

**Keywords:** fuzzy logic, multi-criteria decision making, dormitory allocation, student preferences, recommendation system, social compatibility, additive weighting method.

**Introduction.** The management of student accommodation in dormitories is an essential part of campus operations that directly affects student satisfaction, the quality of the educational environment, and the efficient use of campus resources. Despite the growing digitalization of higher education, many institutions still rely on manual or semi-automated room allocation procedures that require significant administrative effort and often fail to adequately account for individual student preferences [1], [2].

To improve decision-making in such environments, universities increasingly adopt intelligent information systems and personalized recommendation approaches. Recommender systems enable the generation of accommodation suggestions based on user preferences and contextual factors, thereby improving the quality of the user experience and adaptation [1], [3].

The dormitory room selection process involves multiple criteria, including budget constraints, room capacity, distance to the university, comfort level, noise conditions, and social compatibility. Many of these criteria are subjective and are naturally expressed in linguistic terms such as

“moderately priced”, “quiet environment”, or “not too many roommates”, which makes it difficult to use deterministic approaches based on strict thresholds.

In this context, fuzzy logic provides an effective framework for representing uncertainty and modeling linguistic preferences in multi-criteria decision-making problems [4], [5]. Therefore, developing a fuzzy-logic-based recommendation component for dormitory accommodation becomes a timely and relevant task to improve the personalization, interpretability, and quality of student housing decisions.

**Literature review.** Most existing dormitory management systems concentrate on routine administrative tasks and offer little support for intelligent decision-making. University accommodation systems typically support application processing, document management, and status tracking, but do not provide personalized room recommendations based on student preferences [6].

Commercial accommodation platforms, such as INGEK, HousingAnywhere, Student.com, and UniAcco, provide filtering by price, location, and room characteris-

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tics; however, their recommendation mechanisms usually rely on direct filtering rather than multi-criteria decision support [7]–[10]. Similar limitations can also be observed in local web-based dormitory solutions [11].

Regarding methodological approaches, multi-criteria decision-making methods, such as the Simple Additive Weighting method, are widely used because of their transparency and computational simplicity. However, such approaches require precise numerical inputs and assume linear relationships between criteria, which limits their applicability in situations involving subjective or linguistic preferences [12], [13].

Data-driven and clustering-based approaches have also been applied to recommendation problems [2], [14]. While they can be effective with large datasets, their interpretability is often limited, which reduces their usefulness in real decision-support settings.

Fuzzy logic provides a flexible and interpretable framework for modeling uncertain and linguistically expressed user preferences in multi-criteria environments [4], [5]. At the same time, optimization approaches, including genetic algorithms, have proven effective for solving related allocation problems under constraints [15], [16].

Therefore, existing dormitory systems do not adequately combine personalized preference modeling, social compatibility assessment, and interpretable multi-criteria evaluation. This motivates the development of the proposed fuzzy-based recommendation approach.

**Problem Statement.** The problem of student accommodation selection can be formulated as a multi-criteria decision-making problem under uncertainty, in which the degree of suitability between students and available dormitory rooms must be evaluated based on individual preferences and room characteristics.

Let  $d$  denote the set of students,  $R = \{r_1, r_2, \dots, r_m\}$  – the set of available rooms, and  $C = \{c_1, c_2, \dots, c_k\}$  – the set of evaluation criteria, which includes price, distance to the university, noise level, room capacity, comfort, renovation condition, and social compatibility. Each student provides their preferences for these criteria in linguistic terms (e.g., low price, quiet environment, moderate distance), which are subjective and cannot be directly encoded as precise numerical values; for example, an acceptable price level is “medium”. At the same time, each criterion is assigned a weight that reflects its relative importance for a particular student.

The central objective of the problem is to determine how well each room satisfies a given student’s preferences. This is achieved by calculating a compatibility score for each student–room pair:

$$F_{ij} = \sum_{l=1}^k w_{il} \cdot d_{ijl},$$

where  $l$  is the index of the criterion,  $w_{il}$  represents the importance of the criterion  $c_l$  for student  $s_i$ , and  $d_{ijl} \in [0,1]$  denotes the partial compatibility of the room  $r_j$  with respect to this criterion. The values  $d_{ijl}$  are obtained using

fuzzy inference or rule-based evaluation depending on the criterion, which transform both linguistic preferences and quantitative room characteristics into a unified numerical scale.

Once the compatibility scores are computed, the recommendation task becomes a ranking problem. For each student, all available rooms are evaluated and ordered in descending order of  $F_{ij}$ , and this ordering forms a personalized list of recommended options. Such a formulation focuses on identifying the most suitable alternatives for each individual student rather than performing a global allocation of all students simultaneously.

The main challenge in this problem lies in processing heterogeneous and partially subjective criteria. For example, preferences such as an acceptable price level or desired comfort are inherently vague, and trade-offs between criteria (for example, lower price versus higher comfort) also complicate the evaluation process. These characteristics limit the effectiveness of classical linear and deterministic models.

To address these challenges, the proposed approach uses fuzzy logic to model uncertainty and linguistic preferences. The resulting compatibility scores offer an interpretable, flexible basis for generating personalized room recommendations. The obtained ranking can further serve as input to more advanced allocation models, which may be considered a direction for future research.

**Method.** The proposed method considers the problem of assigning students to dormitory rooms as a multi-criteria decision-making task under uncertainty. Each student is evaluated for all available rooms based on individual preferences and room characteristics, while the vagueness of human judgments is handled using fuzzy logic. Social compatibility is incorporated through an additional rule-based component.

Let  $S = \{s_i\}$  denote the set of students and  $R = \{r_j\}$  the set of available rooms. Each student  $s_i$  is described by a vector of preferences  $\mathbf{P} = (p_{i1}, \dots, p_{ik})$  and a corresponding vector of weights  $\mathbf{W}_i = (w_{i1}, \dots, w_{ik})$ , where

$$\sum_{l=1}^k w_{il} = 1.$$

Each room  $r_j$  is described by a vector of parameters  $\mathbf{X}_j = (x_{j1}, \dots, x_{jk})$ , where  $x_{jl}$  represents the value of room  $r_j$  corresponding to criterion  $c_l$ .

For each pair  $(s_i, r_j)$ , the model computes partial scores  $d_{ijl} \in [0,1]$ , where index  $l$  corresponds to a specific criterion (e.g., price, distance, noise, comfort). These scores are obtained through fuzzy inference or rule-based evaluation, depending on the criterion. First, both student preferences and room parameters are transformed into linguistic variables using predefined membership functions (e.g., low, medium, high), typically represented by triangular or trapezoidal fuzzy sets. Then, Mamdani-type inference is applied using a rule base of the form:

IF room parameter is A  
 AND preference is B  
 THEN suitability is C.

The resulting fuzzy output is defuzzified using the centroid method, yielding a crisp value  $d_{ij}$ .

In addition to the considered criteria, the method incorporates a social compatibility component that reflects the feasibility of co-living among students. This covers aspects such as language, cultural background, and lifestyle preferences. For instance, language compatibility is evaluated not only by the presence of identical languages but also by students' ability to communicate through a shared language. English often serves as a common communication medium; therefore, in international dormitory environments. So, if two students do not share a native language but both can communicate in English, partial compatibility is assigned. Otherwise, compatibility is minimal. The resulting social score is denoted as  $d_{soc} \in [0,1]$  and is treated as a partial score corresponding to the social compatibility criterion. Thus, social compatibility is incorporated into the model as an evaluation criterion and contributes to the overall compatibility score in the same manner as the other criteria.

The overall compatibility between student  $s_i$  and room  $r_j$  is computed by aggregating all partial scores using  $F_{ij}$ .

Thus, for each student, the method iteratively evaluates all available rooms by performing fuzzification, inference, defuzzification, and aggregation steps, storing the results in a matrix  $F = [F_{ij}]$ . Rooms are then ranked in descending order of  $F_{ij}$ , producing a personalized recommendation list.

The overall workflow of the method, including the stages of fuzzy evaluation and aggregation described, is illustrated in Fig. 1.

**Results and Discussion.** The experimental dataset was constructed based on domain expertise and direct communication with international and Erasmus students, which enabled the identification of the most relevant accommodation criteria and typical preference patterns for both short-term and long-term residents. This approach ensured that

the dataset reflects realistic decision-making scenarios and incorporates both quantitative room characteristics and subjective user preferences.

Three dormitories with different accommodation conditions were modelled to evaluate the behavior of the proposed approach under varying trade-offs between criteria. Dormitory A is located close to the university and is characterized by relatively low noise levels and moderate comfort. Dormitory B is farther away but offers better renovation conditions. Dormitory C is located in a central area, offering greater comfort but also higher prices and increased environmental noise. Such differentiation allows testing the model's sensitivity to conflicting criteria and realistic decision-making scenarios.

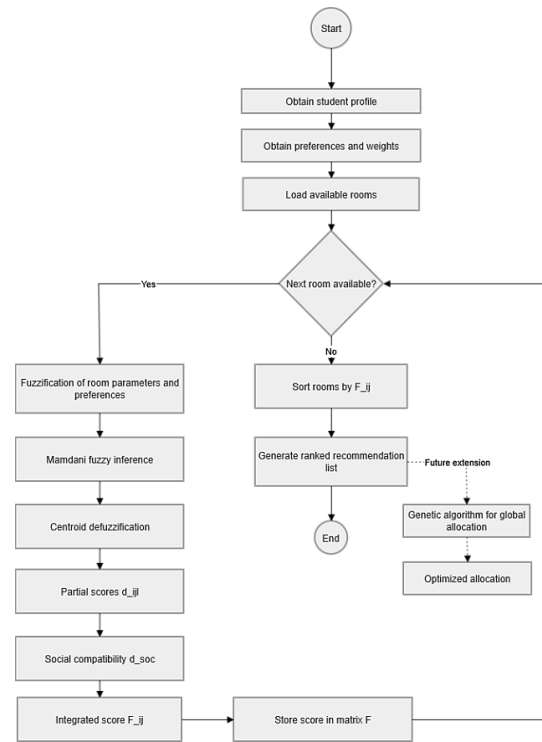


Fig. 1. Flowchart of the fuzzy-based room recommendation algorithm

In contrast to a flat dataset representation, the experimental data were organized according to the relational structure of the developed system. The dataset includes multiple interconnected tables describing students, their

Table 1 – Relational data used in the experiment

Table	Role in the experiment
USERS	Stores student profiles and social characteristics
STUDENT_PREFERENCES	Stores linguistic accommodation preferences
STUDENT_PREFERENCE_WEIGHTS	Stores individual criterion weights
HOSTELS	Describes dormitory-level characteristics
ROOMS	Stores room parameters used in recommendation
BEDS	Defines bed places within rooms
CURRENT_ASSIGNMENTS	Stores already occupied beds and current residents
MODEL_PARAMETERS	Stores model parameters for social compatibility
RECOMMENDATION_LOG / output file	Stores calculated scores and ranking results

preferences and weights, and dormitory and room characteristics. The main entities involved in the experiment and their roles are summarized in Table 1.

Such a structure allows separating static information (room parameters, dormitory characteristics) from dynamic user-specific data (preferences and weights), which is essential for evaluating the recommendation model.

The recommendation results were obtained by computing partial compatibility scores for each criterion and aggregating them into the final compatibility score –  $F_{ij}$ . In Table 2,  $d_{price}$ ,  $d_{noise}$ , and  $d_{soc}$  denote normalized partial compatibility scores for the price criterion, noise level, and social compatibility, respectively, where each value belongs to the interval [0,1]. A fragment of the computed results is presented in Table 2, where each row corresponds to a specific student–room pair.

Table 2 – Fragment of calculated recommendation results

Student	Room	$d_{price}$	$d_{noise}$	$d_{soc}$	$F_{ij}$	Rank
Ayse Demir	A101	0.500	0.790	0.575	0.732	1
Ayse Demir	A103	0.500	0.790	0.500	0.727	2

To better understand the behavior of the proposed method, several representative student profiles were analyzed in detail. The selected students differ in their preference structures, allowing evaluation of the model under different decision-making scenarios. For example, some students demonstrate strong preferences for comfort and low noise levels, while others prioritize price or social compatibility. These differences in preference structures directly influence the resulting compatibility scores and ranking outcomes.

The results demonstrate that the proposed fuzzy-based method yields distinct compatibility scores across rooms, even when the initial parameters are similar. This is primarily due to the use of fuzzy inference, which captures gradual transitions between linguistic categories (e.g., “low”, “medium”, “high”) instead of relying on strict thresholds.

To further assess the effectiveness of the proposed approach and to better interpret the results, the outcomes were compared with those of the Simple Additive Weighting (SAW) method, which is widely used in multi-criteria decision-making problems due to its simplicity and interpretability. In SAW, all criteria are normalized and aggregated linearly using predefined weights, without explicitly modelling uncertainty or linguistic preferences. This makes SAW a suitable baseline for comparison with more advanced approaches [17].

In the SAW method, each criterion is first normalized to a comparable scale, taking into account its type (benefit or cost), after which the overall score is calculated as a weighted sum of criterion values. The same criteria and weights were used for both methods in this study to allow a fair comparison. The key distinction appears at the evaluation stage: the proposed approach uses fuzzy

inference, whereas SAW performs a direct weighted aggregation of numerical values.

A comparison with the SAW method reveals important differences in ranking behavior. While SAW often produces identical or very close scores for multiple alternatives, the fuzzy-based approach introduces additional sensitivity to variations in criteria values and better reflects subjective preferences. This effect is especially noticeable in cases where trade-offs between criteria are present.

The comparison in Table 3 shows that both methods yield similar results for students with clearly dominant preferences and homogeneous room characteristics. For instance, students such as Ayse Demir and Luka Horvat receive nearly identical recommendations from both methods, which indicates that their preference structures clearly match the characteristics of the top-ranked rooms.

However, noticeable differences appear in more complex cases. In particular, for students such as Elif Kaya and Mehmet Arslan, the fuzzy-based method produces rankings that differ from those obtained using SAW. This can be explained by the structure of their preferences, in which no single criterion dominates and multiple trade-offs must be considered.

For example, Elif Kaya assigns relatively balanced importance to several criteria, including distance, noise, and comfort. In such cases, the fuzzy-based method captures partial satisfaction across multiple criteria, whereas SAW tends to favor alternatives with slightly higher normalized values, resulting in different rankings.

Table 3 – Comparison of top-ranked rooms using the Fuzzy method and SAW

Student	Method	Rank 1	Rank 2	Rank 3
Ayse Demir	Fuzzy	A101	A103	A104
Ayse Demir	SAW	A101	A103	A104
Elif Kaya	Fuzzy	A309	A310	A311
Elif Kaya	SAW	A303	A304	A305
Luka Horvat	Fuzzy	C308	C309	C310
Luka Horvat	SAW	C308	C309	C310
Mehmet Arslan	Fuzzy	B114	A113	A317
Mehmet Arslan	SAW	A317	A318	A319

Similarly, for Mehmet Arslan, the inclusion of the social compatibility component significantly influences the final ranking. The fuzzy-based method prioritizes rooms with better social matching, whereas SAW does not explicitly account for such relationships, leading to different top-ranked options.

In addition to individual comparisons, the overall behavior of the proposed method was analyzed based on the distribution of compatibility scores across all evaluated student–room pairs.

Fig. 2 illustrates the distribution of compatibility scores  $F_{ij}$  obtained for all evaluated student–room pairs. The majority of values fall between 0.68 and 0.71,

indicating the overall consistency of the evaluated accommodation options with student preferences.

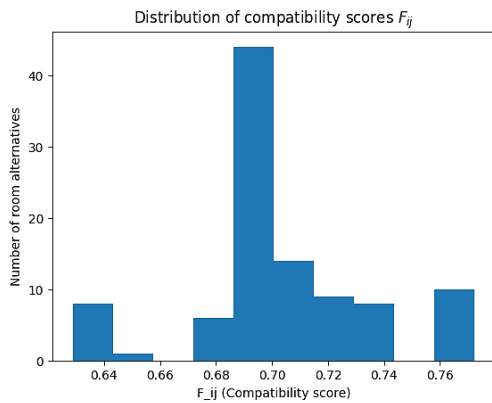


Fig. 2. Distribution of compatibility scores  $F_{ij}$  for all evaluated student–room pairs

At the same time, the presence of both lower and higher values indicates that the model can distinguish between less and more suitable alternatives. In particular, rooms with significantly higher scores (above 0.74) correspond to cases where multiple criteria are simultaneously well satisfied, while lower scores reflect partial mismatches in one or more criteria.

Such a distribution confirms that the proposed fuzzy-based approach provides a balanced evaluation of alternatives and avoids excessive clustering of results. This is especially important in recommendation scenarios, where small differences in scores determine the final ranking of options.

The fuzzy-based method and SAW method exhibit different score distributions (Fig. 3). The fuzzy-based method yields more concentrated compatibility scores in the middle range, whereas SAW produces several groups of values due to linear normalization and aggregation. This confirms that the proposed and baseline methods rank alternatives using different evaluation mechanisms.

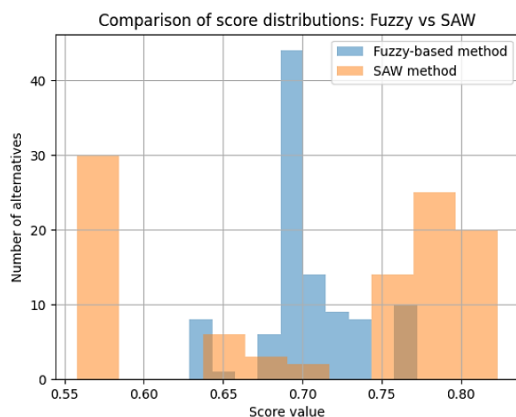


Fig. 3. Comparison of score distributions obtained using the fuzzy-based method and the SAW method

A more detailed analysis of Fig. 3 shows that the SAW method tends to produce several distinct clusters of scores, which is a direct consequence of linear normalization and

aggregation. As a result, multiple alternatives receive identical or nearly identical values, reducing the discriminative ability of the ranking.

In contrast, the fuzzy-based method produces a smoother and more continuous distribution of scores. This behavior reflects fuzzy inference's ability to model gradual transitions between preference levels and capture partial satisfaction of criteria. Consequently, the proposed approach provides a more nuanced differentiation between alternatives, which is particularly important in scenarios with closely competing options.

Overall, the experimental results demonstrate that the proposed fuzzy-based approach provides a more flexible and sensitive evaluation of accommodation alternatives compared to the SAW method. This is especially clear in situations with several trade-offs and subjective criteria, where handling uncertainty and partial preferences becomes important.

**Conclusions.** This study proposes a fuzzy-logic-based recommendation approach for selecting student dormitory rooms, formulated as a multi-criteria decision-making problem under uncertainty. The method allows the incorporation of both quantitative room characteristics and linguistically expressed subjective student preferences.

The developed model integrates fuzzy inference to evaluate partial compatibility across multiple criteria and includes a social compatibility component that reflects the feasibility of co-living among students. This allows the model to better reflect how students actually make decisions.

The results show that the proposed method produces more differentiated and interpretable rankings compared to the Simple Additive Weighting (SAW) method. While SAW tends to generate identical or closely grouped scores due to linear aggregation, the fuzzy-based approach captures gradual transitions between preference levels and accounts for partial satisfaction of criteria.

The comparison also shows that both methods provide similar results in cases with dominant criteria; however, significant differences arise in more complex scenarios involving multiple trade-offs and social factors. In such cases, the proposed approach demonstrates higher sensitivity to variations in input parameters and better reflects individual preferences.

Therefore, the proposed method can serve as an effective tool for personalized dormitory room recommendation. It may serve as a decision-support component within dormitory management systems, improving the quality of allocation decisions and user satisfaction.

Future research may focus on integrating the proposed recommendation model with global optimization techniques, such as genetic algorithms, to solve the full allocation problem under capacity constraints.

**Declaration on the use of generative AI.** During the preparation of this work, the authors used ChatGPT and Grammarly for grammar and spell checking, as well as for rephrasing and reformulating the text. After using these tools, the authors reviewed and edited the content as necessary and take full responsibility for the content of this publication.

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### НЕЧІТКА ЛОГІКА В РЕКОМЕНДАЦІЙНИХ СИСТЕМАХ ПОСЕЛЕННЯ В ГУРТОЖИТКАХ: УРАХУВАННЯ НЕВИЗНАЧЕНОСТІ ТА ЛІНГВІСТИЧНИХ УПОДОБАНЬ СТУДЕНТІВ

Задача розподілу студентів по кімнатах гуртожитку розглядається як задача багатокритеріального прийняття рішень в умовах невизначеності. Актуальність дослідження зумовлена необхідністю підвищення якості процесів поселення за рахунок використання інтелектуальних рекомендаційних підходів, що враховують індивідуальні вподобання студентів, на відміну від простих механізмів фільтрації. Метою роботи є розроблення рекомендаційної моделі, яка оцінює придатність кімнат гуртожитку на основі як кількісних характеристик, так і суб'єктивних вподобань користувачів. Для досягнення цієї мети застосовано підхід нечіткої логіки для моделювання лінгвістичної природи вимог користувачів та врахування невизначеності в процесі прийняття рішень. Запропонована модель обчислює часткові оцінки сумісності за декількома критеріями, зокрема ціною, відстанню, комфортом, рівнем шуму та соціальною сумісністю, та агрегує їх у загальну міру придатності для кожної пари «студент–кімната». Ефективність підходу оцінюється шляхом порівняння з методом Simple Additive Weighting, який використовується як базовий. Результати показують, що підхід на основі нечіткої логіки забезпечує більш диференційовані та гнучкі рекомендації, краще відображає різноманітність уподобань студентів і підвищує якість ранжування альтернатив. Аналіз розподілу оцінок показує, що підхід нечіткої логіки формує більш гладкий і безперервний діапазон значень сумісності, тоді як метод адитивного зважування має тенденцію до утворення кластеризованих значень, що знижує здатність розрізняти альтернативи. Запропонований метод може бути використаний як інструмент підтримки прийняття рішень у системах управління гуртожитками для підвищення ефективності розподілу та задоволеності користувачів.

**Ключові слова:** нечітка логіка, багатокритеріальне прийняття рішень, розподіл у гуртожитку, вподобання студентів, рекомендаційна система, соціальна сумісність, метод адитивного зважування.

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