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Evaluating the Performance of Khizana Ezziania Library in Kenadsa, Algeria: A Qualitative and Quantitative Assessment

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***Abstract*— this study investigates the performance of the Khizana Ezziania Library, a heritage building located in Kenadsa, an oasis settlement in Algeria. Employing a mixed-method approach, the evaluation integrates qualitative and quantitative data to assess thermal and luminous conditions, user perceptions, and spatial behaviors. In situ measurements of physical parameters are complemented by questionnaires capturing sensory experiences and behavioral patterns of users in different spaces. Additionally, an** agent-based modeling (ABM) method **is applied to simulate user movement and interaction within the library, providing deeper insights into spatial dynamics and usage patterns. The findings reveal the intricate interplay between architectural design, environmental conditions, and user satisfaction in this historic library, offering valuable recommendations for preserving and adapting heritage buildings for contemporary use.**

***Keywords*— Khizana Ezziania Library, Thermal Comfort, Luminous Environment, User Perception, Spatial Behavior, Agent-Based Modeling (ABM).**

I. INTRODUCTION

Libraries have long served as cultural repositories, reflecting the societal values, knowledge systems, and architectural advancements of their time. The **Khizana Ezziania Library**, located in the oasis town of **Kenadsa, Algeria**, stands as a testament to the region's **rich heritage and traditional architectural style** [1]. Constructed using **local materials** and designed to withstand the **harsh climatic conditions** of the Saharan environment, this library exemplifies **sustainable vernacular design**. Heritage buildings play a crucial role in preserving **cultural identity** and fostering **community engagement** [2]. The Khizana Ezziania Library, situated in the historic **oasis settlement of Kenadsa**, is a prime example of **Saharan architecture**, characterized by intricate designs, passive environmental strategies, and **spatial configurations that respond to local climatic and cultural needs**. However, as contemporary demands evolve, it becomes essential to evaluate such buildings not only for their **historical and aesthetic significance** but also for their **functional performance and usability** [3].

The role of **user perception** in evaluating building performance has gained increasing attention in recent years [4]. Studies highlight that understanding **how occupants interact with architectural spaces** provides critical insights into their **functionality and user satisfaction**. While **quantitative approaches** assess measurable factors such as **temperature, lighting levels, and energy efficiency**, **qualitative methods** explore **behavioral and emotional responses** to space, capturing nuanced user experiences [5]. This study employs both approaches, incorporating **Agent-Based Modeling (ABM)** to simulate **user movement, interaction, and spatial behavior** within the library [6]. Traditional architecture in **oasis regions** like Kenadsa has been widely studied for its **climatic adaptability and aesthetic significance** [7]. Scholars such as **Fathy (1986)** have emphasized the role of **vernacular design in creating sustainable and contextually appropriate built environments** [8]. However, research on **user behavior and spatial utilization** in such spaces remains limited, particularly in the **North African context [4]**. By integrating **qualitative analysis, quantitative assessments, and ABM simulations**, this study seeks to provide a comprehensive evaluation of the **Khizana Ezziania Library's architectural performance**. ABM allows for the **exploration of**

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occupancy patterns, circulation flows, and adaptive behaviors, offering valuable insights into **how heritage buildings accommodate contemporary user needs**. This approach contributes to broader discussions on **heritage conservation, adaptive reuse, and sustainable design**, emphasizing the need for interventions that enhance usability while preserving historical authenticity.

II. Research Methodology

This study employs a mixed-method approach to understand the perceptions, experiences, and spatial behaviors of Khizana Ezziania Library users, integrating qualitative and quantitative research methods with Agent-Based Modeling (ABM) to analyze occupant interactions within the space.

1. Semi-Structured Interviews – Conducted with 20 participants, including library staff, frequent users, and occasional visitors. Questions focused on their experiences of thermal comfort, functionality, and the symbolic aspects of the library.
2. Focus Group Discussions – Two sessions with five participants each facilitated discussions on the library's design, ambiance, and spatial usability, uncovering collective insights into user experiences.
3. Direct Observation – Observations conducted at various times of the day documented patterns of use, spatial interactions, and environmental factors such as light, temperature, and ventilation.

A. Stage One: Physical Context and Case Study

Over the past decades, **Kenadsa** has undergone significant transformations [7], impacting its **architectural development, environmental sustainability, and energy consumption** across different historical periods. These changes have influenced **user perception and spatial behaviors**, particularly in heritage buildings such as the **Khizana Ezziania Library**.

- Pre-Colonial Period/ Post-Colonial Period**.**

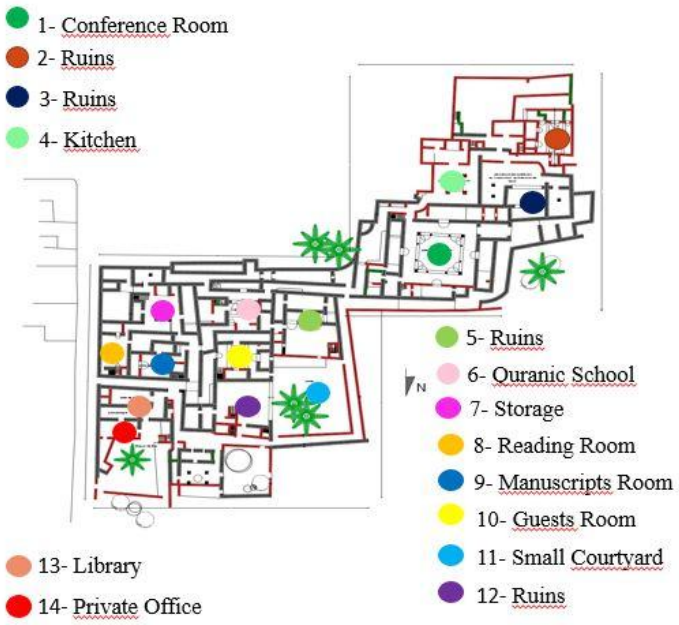

Fig. 01Khizana Ezziania's Library floor planning "Actual Spaces". Source: Authors 2024.

Urban Context and Integration **The** Khizana Ezziania Library **is seamlessly embedded within the** dense, maze-like fabric **of the** Ksar of Kenadsa**, a** fortified village typical of Saharan oases**. Its close integration with surrounding structures** reduces thermal exposure, enhances structural stability, and promotes passive cooling**. Strategically located near the** mosque and key communal spaces**, the library serves as**

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a cultural and intellectual hub**, reinforcing its role as a** repository of knowledge and a pillar of historical continuity **within the** social and educational fabric **of the settlement.**

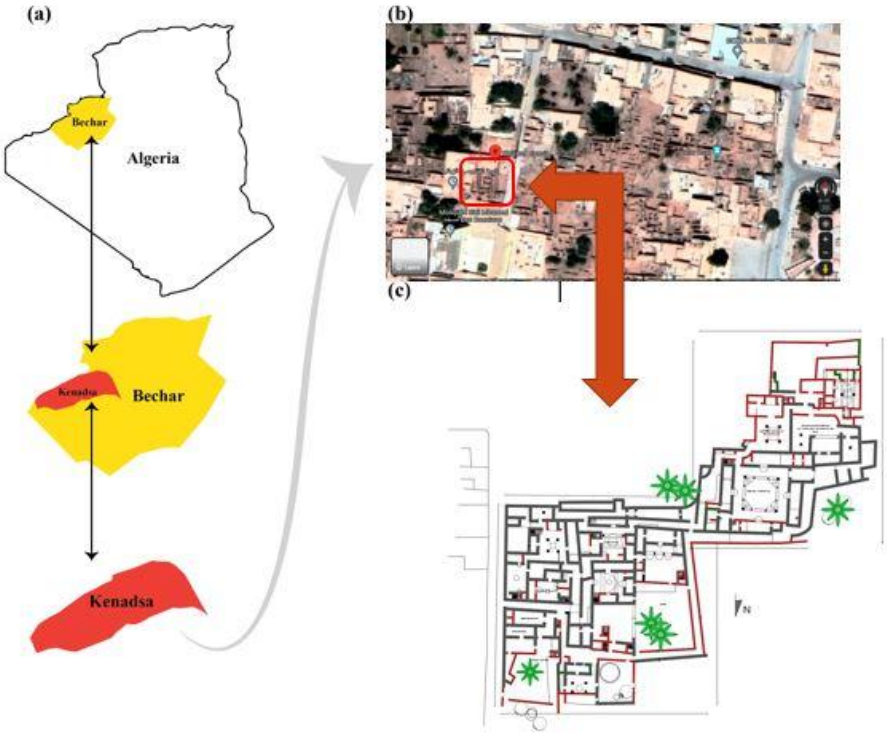

Fig. 02 Location of Khizana Ezziania Library. Source: Authors 2024.

The **Khizana Ezziania Library** features a **well-organized floor plan** centered around a **traditional courtyard**, which enhances **natural light, ventilation, and passive cooling**. Surrounding this core space are **functional zones**, including **reading rooms for study**, **insulated storage for manuscripts**, and **administrative areas**. This layout supports the library's dual function as both an **educational hub and a heritage site**.

Fig. 03 Central countyard of Khizana Ezziania [9].

B. Stage two: Subjective Approach and Used Questionnaire:

This questionnaire framework is designed to capture user experiences with **sensory and behavioral aspects** of indoor environments, offering **in-depth insights** into how individuals interact with and perceive heritage spaces like the **Khizana Kandousia Library**. Focusing on the **thermo-visual experiences of individuals** to

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assess **the multisensory perceptual dimensions** within each indoor environment of the case study and to extract **the behaviors and perceptions of each user and energy consumption of each office.**

The surveys seek **to identify unfriendly behaviors,** that may have a **more significant environmental footprint and higher energy consumption** and **friendly behaviors that help to reduce the building's energy consumption** and to emphasizing actions that contribute to **minimal impact and respect for the building's heritage value [4].**

Table 01. Represents the construction of the 07 questionnaires [10].

Category	Questions	Purpose
1. General Experience	- How would you describe your overall experience in the library? - What do you think makes this library unique compared to others?	To understand the general user satisfaction and initial impressions. To identify the cultural and architectural distinctiveness of the space.
2. Spatial Functionality	- Are the spaces within the library easy to navigate and use? - Are there any areas within the library that you feel are overcrowded or underutilized?	To assess the spatial layout and functionality. To evaluate the effectiveness of space allocation.
3. Environmental Comfort	- How comfortable do you feel in terms of lighting, temperature, and acoustics in the library? - Are there any specific areas where you feel uncomfortable? Why?	To gather user perceptions of environmental conditions such as lighting, thermal comfort, and sound. To identify problem zones within the library.
4. Architectural Features	- What do you think about the traditional design elements of the library? - Do you feel that the building design enhances or hinders your experience?	To gauge user appreciation of traditional architectural features. To assess the influence of architectural elements on user behavior and satisfaction.
5. Cultural Significance	- What does this library mean to you personally or to the community? - How well do you think the library preserves its historical identity?	To explore the cultural and emotional value of the library for users. To evaluate the perceived cultural authenticity of the building.
6. User Interaction	- How do you typically use the library? For reading, research, or other purposes? - Are there any specific spaces or features you prefer when you are in the library?	To analyze user behavior and activities within the space. To understand user preferences and interaction with specific spaces.
7. Suggestions for Improvement	- What changes would you suggest to improve your experience in the library? - Are there any additional features or spaces you would like to see in the library?	To gather user recommendations for enhancing the library's performance. To identify user needs and areas for potential development.

C. Stage Three: Objective Approach and In Situ Measurements:

As **the red circles** denote the **measurement stations** (figure 4)(data are gathered to paint a detailed picture of the building's environmental characteristics). These measurements are conducted using a "luxmeter kit" compatible with the "Testo 480 multifunctional meter"(end of June and beginning of July), 1pm extreme temperature) The purpose of these physical measurements is to capture the current conditions within the building, shedding light on the actual state of the environment.

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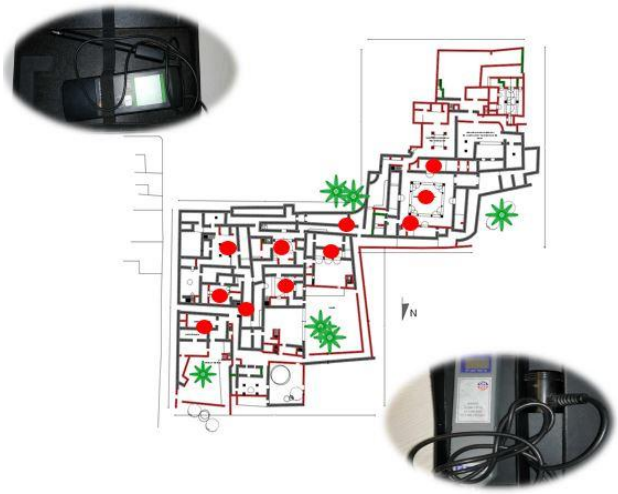

Figure 04. Measurements stations in the library, Source: Authors 2024.

III. RESULTS AND DISCUSSION

A. Distribution of the Physical Dimensions of the Environment during the Work Hours

Places with illumination level vary between 0, 18 and 3, 77 lux, comfort thermal level for occupant from neutral to slightly warm. User discomfort is primarily attributed to direct solar radiation exposure, particularly evident in places 01, 02 (central courtyard area) and places 03, 04, 05, 06, 07, 09 and 10 (Reading zone). Conversely, in places shaded and neighbored by the other parts of the Ksar (traditional urbanization), a significant temperature difference of 8.50 ◦C was observed, particularly in the building part's northern-oriented offices. Impact of solar exposure and orientation on indoor offices,

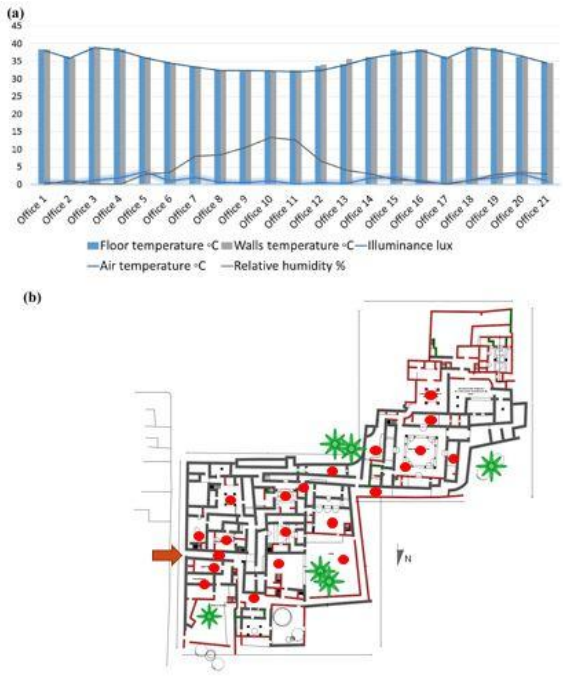

Fig. 04 Distribution of the Physical Dimensions of the Environment during the Work Hours [4].

B. Perceptual Data Analysis: On-Site Questionnaire with Users

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Following the completion of the qualitative analysis and the identification of user office and space behaviors within the building, we organize the findings into three classification packages.

1. **Perception and behaviors package:** This package encompasses the **perception and behaviors of users during each period (Winter/Summer)** under the current **thermal and light conditions.**
2. **Office information package:** This second package provides details on offices, including **the number of users, office location within the building (north, south, east, west), behavior type (Winter/Summer), and the duration of each behavior.**
3. **Behavior code package:** this third package catalogs **each behavior along with its corresponding code,** facilitating modeling within the software. For instance, **thermal behavior 1 is represented as TB1.**

Table 03. **The identification of user's behaviors and its duration in each office/ space (w.winter, s.summer) [4].**

Place	Location	Number of Users	Behaviors	Duration of the Behavior
01	Northern side	02	20 (2, 1), 17 (0,−1), 18 (3)w, 19 (1,−1), 18 (1,0,−1)s, 22 (1w,−1w, 1s,−1s), 21(0).	23 (−2), 24 (0), 25 (−1).
02	Northern side	02	20 (−2), 17 (0), 18 (1)w, 19 (1,−2), 18 (0,−1)s, 22 (−1w,−1s), 21(0).	23 (−2), 24 (−2), 25 (−2).
03	Northern side	03	20 (2, 1), 17 (−1), 18 (3)w, 19 (−2), 18 (2,1)s, 22 (1w,−1w, 1s,−1s).	23 (−1), 24 (−1), 25 (−2).
04	Northern side	01	20 (−2), 17 (2), 18 (3)w, 19 (−2), 18 (−1)s, 22(1w,−1w,−1s), 21(0).	23 (−2), 24 (−1), 25 (−1).
05	Northern side	02	20 (2), 17 (2), 18 (3)w, 19 (0,−1), 18 (−1)s, 22 (1w,−1w,−1s), 21(0).	23 (0), 24 (−1), 25 (−1).
06	Northern side	03	20 (2, 1), 17 (2,0), 18 (3)w, 19 (2,1,−1,−2), 18 (−1)s, 22 (1w,−1w,−1s).	23 (−1), 24 (−1), 25 (−1).
07	Northern side	02	20 (2, 1), 17 (2), 18 (3)w, 19 (−2), 18 (−1,−2)s, 22 (1w,−1w), 21(0).	23 (−1), 24 (−1), 25 (−1).
08	East side	02	20 (2, 1), 17 (−1), 18 (−1)w, 19 (1,−2), 18 (−1,−1)s, 22 (1w,−1w, 1s,−1s), 21(0).	23 (−1), 24 (−1), 25 (−1).
09	Southern-east side	01	20 (1, −2), 17 (−1), 18 (−1)w, 19(−2), 18 (0,−1)s, 22 (−1w,−1s), 21(0).	23 (0), 24 (−1), 25 (0).
10	Southern-east side	02	20 (2, 1), 17 (0,−1), 18 (3)w, 19 (0,−1), 18 (−1)s, 22 (1w, 1s), 21(0).	23 (−1), 24 (−1), 25 (0).
11	Southern-west side	02	20 (2, 1), 17 (2,0), 18 (3)w, 19 (1,−1), 18 (−1)s, 22 (1w, 1s), 21(0).	23 (−1), 24 (−1), 25 (0).
12	Southern side	04	20 (2, 1), 17 (0), 18 (1)w, 19 (1,0), 18 (1,−1)s, 22 (1w,−1w, 1s,−1s), 21(0).	23 (−1), 24 (−2), 25 (−2).
13	Middle side	04	20 (2, 1), 17 (0), 18 (1)w, 19 (1,0), 22 (1w,−1w,−1s), 21(0).	23 (0), 24 (−2), 25 (−1).
14	Middle side	01	20 (2, 1), 17 (0,−1), 18 (3)w, 19 (1,−1), 18 (1,−1)s, 22 (1w,−1w, 1s), 21(0).	23 (0), 24 (−1), 25 (−1).
15	Southern-west side	01	20 (2, 1), 17 (1), 18 (1,−1)w, 19 (1,0), 18 (1,−1)s, 22 (1w,−1w,−1s), 21(0).	23 (−1), 24 (−2), 25 (−2).
16	Southern-west side	02	20 (2, 1), 17 (0), 18 (3)w, 19 (1,−1), 18 (2,1,−1)s, 22 (1w,−1w, 1s,−1s), 21(0).	23 (−2), 24 (−1), 25 (−1).
17	Southern-west side	02	20 (2, 1), 17 (0), 18 (3)w, 19 (1,−1), 18 (2,1,−1)s, 22 (1w,−1w, 1s,−1s), 21(0).	23 (−2), 24 (−1), 25 (−1).
18	Southern-west side	01	20 (2, 1), 17 (0), 18 (3)w, 19 (1,−1), 18 (2,1,−1)s, 22 (1w,−1w, 1s,−1s), 21(0).	23 (−2), 24 (−1), 25 (−1).
19	Northern side	02	20 (2, 1), 17 (1), 18 (1,−1)w, 19 (1,0), 18 (1,−1)s, 22 (1w,−1w,−1s), 21(0).	23 (−1), 24 (−2), 25 (−2).

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20	Northern and southern side	04	20 (2, 1), 17 (1), 18 (1,−1)w, 19 (1,0), 18 (1,−1)s, 22 (1w,−1w,−1s), 21(0).	23 (−1), 24 (−2), 25 (−2).
21	Northern side	03	20 (2, 1), 17 (2,0), 18 (3)w, 18 (1,−1), 18 (−1)s, 22 (1w, 1s), 21(0).	23 (−1), 24 (−1), 25 (0).

Various places within the case study, including their location, the number of users, observed behaviors, and the duration of these behaviors. Each place is identified by a unique number and is situated on different sides of the building. The focal point is the behaviors observed in each place, denoted numerically and detailed with sub-behaviors in parentheses. For instance, behavior 20 may have sub-behaviors like 2 and 1. The duration of each behavior is also outlined, such as the duration of behavior 23 with an intensity of −2. Places in the same side exhibit similar behaviors and durations. Places who has small windows, use artificial lights more frequently.

C. The codification of user behaviors and their duration in each office for the agent-based modeling

This structured approach simplifies the representation of behaviors in the simulation and facilitate the modeling of user's behaviors. For example, if the first thermal behavior is labeled as TB1 (presumably representing "thermal behavior 1" or a similar designation).

D. Behavior's Agent-Based Modeling Simulation Study

Agent-Based Modeling (ABM) was initiated in **Rhino 7** using the **Quelia Agent** plug-in. additionally, **weather data** for the selected city (**Kenadsa, Bechar**) were **exported from Climate Studio** and integrated into the simulation. Each **user behavior** within the library was modeled with **precise occupancy numbers** in designated areas, considering the **physical environmental conditions**. The plug-in's capabilities were tailored to reflect **real-time thermal and lighting conditions**, incorporating **measured temperature and brightness levels** to ensure an accurate representation of user interactions within the space.

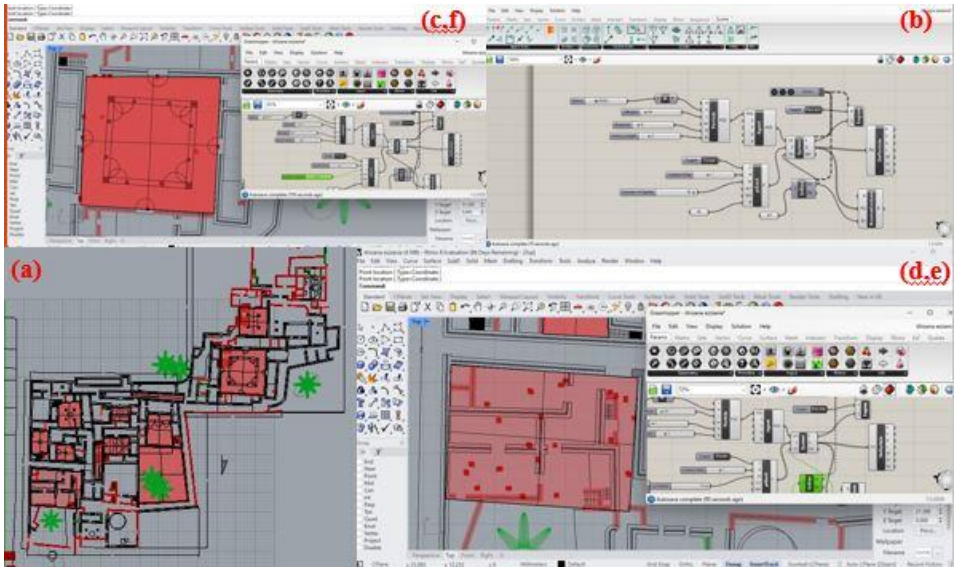

Fig. 05 Representation of the behavior's agent-based modeling simulation study process in Kenadsa's heritage office building: **(a)** user agent in each studied office of the case study, **(b)** modeling process of one office environment, **(c,f)** final modeling process for "all offices", **(d,e)** agent speed and lifespan final result, Source: Authors 2024.

Based on our Agent-Based Modeling (ABM) simulation, we conducted two stages of analysis: one with user behaviors present and another without, to identify the optimal thermal and luminous conditions that maximize user productivity.

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- The lifespan of agents (users) represents the duration of work within the space.
- The movement speed of agents reflects the efficiency and performance speed of users.

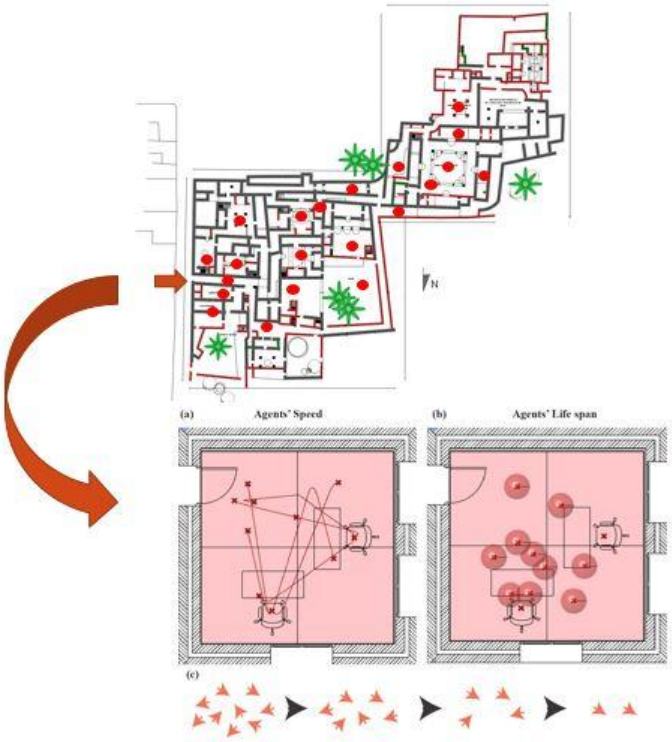

Fig. 06 (a,b) Representation of agents' speed and lifespan in a chosen sample office from Kenadsa's heritage office building: (c) agent's behaviors lifespan "disappearance", (Arrows represent the agents' users), (Source: Authors 2024).

Areas with an optimal luminous and thermal environment**, where users reported** comfort **without engaging in** energy-wasting behaviors**, showed** fast agent movement and quick disappearance**, indicating** high productivity and efficient task execution**. In contrast, areas with** optimal environmental conditions but the presence of energy-wasting behaviors **exhibited** varied performance outcomes**, influenced by inefficient energy use. Meanwhile, areas with the** worst luminous and thermal conditions**, where users reported** discomfort **alongside** energy-wasting behaviors**, demonstrated** slow agent movement and prolonged presence**, reflecting** low productivity and extended task completion times**.**

IV. CONCLUSIONS

This study highlights the critical relationship between architectural design, environmental conditions, and user behavior in heritage spaces, specifically the Khizana Ezziania Library. By integrating qualitative analysis, environmental data, and Agent-Based Modeling (ABM), we gained valuable insights into how users interact with the library's spaces and how thermal and luminous conditions impact their comfort and productivity. The findings emphasize that optimal environmental conditions lead to higher user efficiency, while poor lighting and thermal discomfort result in reduced performance and energy-wasting behaviors. The use of ABM simulations provided a dynamic perspective on user movement and task execution, reinforcing the importance of adaptive reuse strategies that balance heritage conservation with modern functionality. Moving forward, integrating digital tools and real-time data analysis in heritage buildings can enhance both user experience and sustainability. Future research should explore comparative studies across other traditional structures to further validate the role of vernacular architecture in contemporary contexts.

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