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Design for All: Application of Universal Design Principles in Residential and Educational Environments in Bahrain

Zuhair, N
College of Engineering
Gulf University
Sanad 26489, Kingdom of Bahrain
220206100403@gulfuniversity.edu.bh

Alhayki, Z
College of Engineering
Gulf University
Sanad 26489, Kingdom of Bahrain
230206100795@gulfuniversity.edu.bh

Alqassab, M
College of Engineering
Gulf University
Sanad 26489, Kingdom of Bahrain
220206100312@gulfuniversity.edu.bh

Hamada, F
College of Engineering
Gulf University
Sanad 26489, Kingdom of Bahrain
220206100412@gulfuniversity.edu.bh

Job, S
College of Engineering
Gulf University
Sanad 26489, Kingdom of Bahrain
Sandra.job@gulfuniversity.edu.bh

***Abstract*— The research investigates the application of Universal Design principles in residential and educational environments, focusing on both interior and outdoor spaces. By analyzing design elements that enhance accessibility, usability, and inclusivity, the research evaluates the integration of these principles in different spaces to accommodate diverse user needs. A qualitative methodology is used to conduct this study. Case studies in Residential and Educational Environments were conducted to assess compliance with Universal Design standards, highlighting best practices and identifying gaps in implementation. The findings underscore the importance of applying a holistic design approach that fosters equity and functionality, which offers recommendations for architects, interior designers, and policymakers to create more inclusive environments. This research contributes to the growing discourse on sustainable, user-centered design, emphasizing its crucial role in shaping adaptable and equitable living and educational spaces.**

Keywords—Universal Design, Human Factors, Interior Design

I. HUMAN FACTORS IN DESIGN

The discipline of human factors, alternatively termed ergonomics, investigates the interactions between individuals and diverse products, environments, systems, and technologies. Its primary objective is to enhance the design of these elements to maximize human well-being, performance, and overall system efficacy. This field encompasses a broad spectrum of subjects, including social dynamics, physical abilities, cognitive functions, and sensory perceptions. The ultimate aim is to create systems that are safe, efficient, and user-friendly, taking into account human limitations and capabilities. Human factors research finds applications in various domains, such as technological advancement, product development, aviation, and healthcare [1]. In the context of design, human behavior engineering emphasizes three key aspects: usability (ease of use), prioritizing HFE and user-centricity; safety (safe usage), focusing on HFE and market readiness; and desirability (user appeal), considering market potential and user-centricity. [2].

Human factors science focuses on comprehending the physical and cognitive attributes of human capability, examining all facets of human interaction with their surroundings. A contemporary definition of ergonomics characterizes it as a technology aimed at optimizing the relationship between individuals and their activities through the systematic application of human sciences within a system engineering framework [1].

Designers must be aware of human factors science to ensure their product, workplace, or service is safe and socially responsible. The awareness of human factors allows designers to accommodate various percentiles of the population so the majority of people can use and interact with the product or service being designed (ex; designing public places is especially sensitive to these conditions). A designer can use Human Factors, Ergonomics & Anthropometry to their advantage or these things may work against their design. “Good” design observes these qualities first because no one wants to use or own a product or service which carries out the task poorly or dangerously [3]. The act of studying how people use systems or equipment in order to design, develop, and create technology that is safer, more effective, etc. The main goal of Human Factors Engineering (HFE) is to improve user safety by applying what is known about human capabilities and limitations related to all human activities, when evaluating products, facilities, environments or processes [3]. Artifacts is anything such us a product or space designed for human activities/beings. Alteration of artefact, from “artefatto”, from arte, (ablative of art) + factum, from “facio” (made) Any product of human workmanship; applied both to objects made for practical purposes as well as works of art. It is contrasted to natural object, i.e. anything produced by natural forces without the intervention of man. An artifact or artefact is "something made or given shape by man, such as a tool or a work of art, esp. an object of archaeological interest" Basic Human sciences involved are Anatomy, Physiology and Psychology [4].

Understanding anthropometry and ergonomics is essential for designing structures and products that complement the human body. The body comprises bones, muscles, joints,

and organs, where joints provide flexibility, muscles enable movement, and the skeletal system offers structural support. Anthropometric parameters like height, arm reach, and hand size are crucial in designing for diverse users, as varying body shapes influence ergonomic needs. Human motions are categorized into fine (precise), massive (large-scale), involuntary (reflexive), and voluntary (controlled) actions, occurring across the sagittal, frontal, and transverse planes of motion. However, the human body has limitations in strength, stamina, flexibility, vision, and coordination, which affect the amount of force applied or the duration of an activity. The postural system, incorporating the musculoskeletal system, spine, and balance mechanisms like proprioception and the inner ear, ensures alignment and stability, though conditions like scoliosis, kyphosis, and lordosis may disrupt posture. By addressing these factors, designers can create products and environments that reduce physical strain and enhance safety, comfort, and efficiency [5]. Moreover, Human Factors Engineering (HFE) in machine design strives to align machines with tasks and human operators. Task design similarly focuses on matching machines to tasks and tasks to human capabilities. The field of human factors aims to harmonize tasks and machines with human abilities and limitations [2].

Human factors engineering focuses on optimizing human performance, safety, and system usability through practices that prioritize user-centered design. A key aspect is physical ergonomics, which addresses how humans interact with systems, including considerations like posture, force, repetitive tasks such as hammering, and workload periods that may cause stress or strain. Cognitive ergonomics examines how individuals acquire, process, store, and apply information, focusing on perception, attention, memory, and decision-making within bounded systems. Structural anthropometry, a branch of anthropology, involves measurements of skeletal joints essential for designing ergonomic workspaces, products, and environments, while functional anthropometry emphasizes the body's ergonomic characteristics, including strength and range of motion. Safety considerations aim to identify potential risks, implement measures such as warning systems, redundancy, and fail-safe mechanisms, and reduce human error through intuitive designs. Human reliability ensures systems are designed to minimize errors and enhance performance by avoiding mistakes, providing adequate training, managing stress and fatigue, and incorporating feedback mechanisms and user-friendly interfaces. By adhering to these principles, systems become safer, more reliable, and user-focused, reducing errors, improving performance, and enhancing the overall user experience [5]. Significantly, anthropometry, the science of human body measurement, addresses bodily dimensions, movements, and biomechanical aspects, as well as working postures and forces exerted on surrounding objects. It comprises two primary categories of data: structural anthropometric data, which measure bodily dimensions in static positions, and functional anthropometric data, collected during physical activities [1].

To design environments, furnishings, equipment, and systems that put human comfort, safety, and health first, ergonomic guidelines are crucial. These guidelines maximize user performance, lower injury rates, and improve general health [5].

In order to prevent fatigue and improve performance, work tasks should be designed to minimize repetitive motions, difficult postures, and physical strain. Job variation and workload balance should also be considered. Equipment and tools should be simple to use, minimize strain, and be appropriate for the user's physical capabilities. Control interfaces should also offer safe operation and unambiguous feedback. In order to accommodate various body types and avoid musculoskeletal issues, furniture should promote comfort and neutral posture. Workstations and seats should also be adjustable [5]. To encourage comfort and efficiency, the layout of the workspace should reduce needless movement, offer sufficient lighting, and guarantee easy access to controls and equipment. Elevators and ramps are examples of characteristics that should be included in built environments to ensure that they are safe, functional, and comfortable for all users [5].

II. HUMAN FACTORS AND UNIVERSAL DESIGN

The ergonomics approach optimizes human capabilities by designing tasks and equipment for each individual. The seven Universal Design Principles, developed by architects, product designers, engineers, and environmental design researchers, aim to maximize utilization by people with diverse characteristics, including equitable use, flexibility, simplicity, tangible information, tolerance for error, and physical exertion.

1- Equitable Use:

Individuals with diverse abilities should be capable of utilizing and marketing the design. Each user should, when feasible, have access to the same operational method, or an equivalent alternative if necessary. Equal access to privacy, security, and safety features should be provided for all users, and it is essential to avoid stigmatization or isolation of any individual. The layout should be accessible to all users without exclusion. Of paramount importance is ensuring that no consumer's privacy, safety, or security is compromised through product utilization. A notable safety feature in my residence is that all occupants, with the exception of children, can access the lighting controls.

2- Flexibility in Use:

This design accommodates a wide range of individual preferences and ability levels.
Allow consumers to choose how to use it.
Permit access and usage by either the left or the right hand.
Assist the user in becoming more accurate and precise.
Adjust according to the user's speed.
Many different tastes and skill levels are catered for in this design. According to this theory, a design needs to offer choices that the greatest number of clients can select from. Regardless of their preferred approach, users should be able to accurately perform tasks at their own leisure.

3- Simple and Intuitive Use:

The design is easy to use regardless of the user's background, concentration level, or language ability.
Eliminate unnecessary complexity.
Follow the user's intuition and expectations.
Consider a wide range of reading and linguistic proficiency.
Sort information based on its importance.
Efficiently prompt and offer feedback during and after the task is finished.

No matter the user's environment or level of sensory ability, the design successfully conveys the necessary information to them.
Designs should be suitable with the equipment that individuals with physical disabilities may use, and important information should be communicated in a variety of ways, including through the use of words and visuals.

4- Perceptible Information:

No matter the user's environment or level of sensory ability, the design successfully conveys the necessary information to them.
Designs should be suitable with the equipment that individuals with physical disabilities may use, and important information should be communicated in a variety of ways, including through the use of words and visuals.

5- Tolerance for Error:

Its design reduces the dangers and adverse consequences of inadvertent or unintended actions.
The most frequently used and accessible parts should be arranged to minimize hazards and errors; hazardous parts should be taken out, kept apart, or secured.
Alert people to risks and errors.
Provide fail-safe features.
Encourage negligence when carrying out tasks that require attentiveness.
An overlay verifying the purchase and providing the opportunity to reverse the action may appear when a customer inadvertently clicks the "Buy" button on a store's mobile website.
By arranging parts, warning users of possible threats, providing failsafe safeguards, and discouraging negligence in jobs requiring attention, the design reduces risks and errors.

6- Low physical effort:

The design may be used efficiently and enjoyably with little fatigue.
Allow the user to maintain a neutral stance.
Make use of reasonable employees.
Decrease the number of monotonous jobs.
Reduce extended periods of physical activity.
Originally used in architecture, universal design can also be useful when creating digital technology. By reducing complexity or repetitious processes, it lowers user effort.

7- Size and space for approach and use:

Universal design ensures accessibility for all users, regardless of body size, posture, or mobility. It involves providing proper size and space for approach, reach, manipulation, and use, allowing for differences in hand sizes and grips, and providing enough room for personal helpers or assistive technology [6].

III. METHODS

This investigation examines the implementation of universal design principles in residential and educational environments through a case study methodology. The case study approach was chosen for its capacity to provide comprehensive, contextual insights into the effectiveness and challenges of universal design application in specific settings.

Research Design:

The study encompassed four case studies: three residential spaces and one educational facility. These cases were strategically selected based on their reputation for incorporating universal design elements, their geographic and contextual diversity, and their accessibility for on-site research. This selection enabled a comparative analysis of universal design implementation across varied building types and user demographics.

Data Collection Methods:

Data were gathered using the following techniques:
Site Observations: Researchers conducted site visits to document physical design features, spatial configurations, and accessibility elements. Comprehensive field notes and photographic evidence were collected to illustrate the alignment of these spaces with universal design principles.
Usability Assessment: The functionality of each space was evaluated against established universal design criteria, including accessibility, flexibility, and inclusivity, to determine their efficacy in addressing the needs of diverse users.

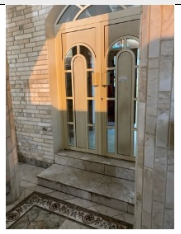
Data Analysis:

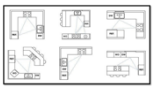
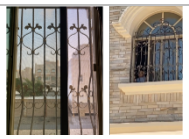
A thematic analysis was performed to identify recurring patterns and themes across residential and educational spaces. The findings were systematically organized to highlight exemplary practices, obstacles, and opportunities for enhancing universal design in these environments. This analytical approach facilitates a thorough understanding of universal design applications in residential and educational settings, contributing to the formulation of evidence-based recommendations for future architectural projects.

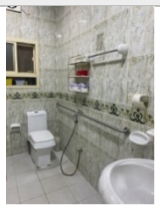
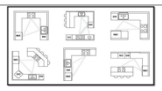
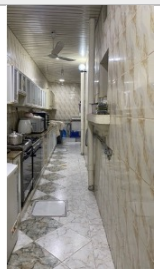
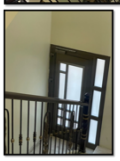
IV. RESULTS

Residential space- 3 houses in Bahrain was investigated from different geographical locations to conduct the study. The findings are shown the table below (Table 1).

TABLE 1: UNIVERSAL DESIGN PRINCIPLES IN RESIDENTIAL SPACES

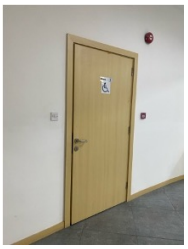
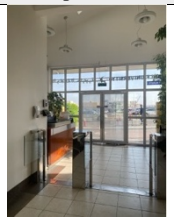
No.	Universal Design Principle in Residential Spaces	
	Principle 1:	***Equitable Use- Findings***
1	 Fig.1. Equitable Use- Ramps	(Ramps) it is not equitable because there are no ramps for the wheelchairs in main door only stairs, maybe there is injuries in one person it will be hard to inter.
2	 Fig.2. Equitable Use- Switches	(switches) everybody in my house can be accessed, except for children, and this is a good thing.

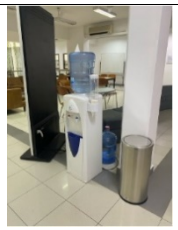
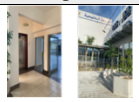
3	 Fig.3. Equitable use - stair	The design is useful and marketable to people with diverse abilities. According to what the first principle stipulates, there is supposed to be a resource for people with special needs that allows access to all groups, even those with special needs. Entry: In this picture (41), there is no ramp for them. The solution is to build a ramp for them to enter
No.	**Universal Design Principle in Residential Spaces**	
	Principle 2:	**Flexibility in Use- Findings**
1	 Fig.4. Flexibility in Use-Storage	(storage) It is flexible the refrigerator and storage in one place it will be easy to reach the stuffs.
2	 Fig.5. Flexibility in Use-Light switch	(Light switch) there is two-way light switch in stairs, that makes it better if the person down no need to go up to close it.
3	 Fig.6. Flexibility in use – kitchen work triangle	The design accommodates a wide range of individual preferences and abilities. In relation to the second principle, flexibility in use, the way the kitchen is designed in homes is in the shape of a triangle, which leads to ease of movement and use, as we can move between the oven, refrigerator, and sink with ease and comfort, which increases the speed of productivity. When there is an error in this design, it will lead to a reduction in productivity.
No.	**Universal Design Principle in Residential Spaces**	
	Principle 3:	**Simple and Intuitive Use-Findings**
1	 Fig.7. Simple and Intuitive Use-Gas Opening	(Gas opening) it is easy to use because it is written on it the way to close and open it.
2	 Fig.8. Simple and intuitive use- door	Use of the design is easy to understand, regardless of the user's experience, knowledge, language skills, or current concentration level. The third principle stipulates intuitive and easy use. It is likely that types of handles will be used for doors in a way that makes it easy for all groups to open the door, whether they are children or people with special needs.
No.	**Universal Design Principle in Residential Spaces**	
	Principle 4:	**Perceptible Information-Findings**
1	 Fig.9. Perceptible Information- Remote control	(Remote control) remote for A/C and TV to change the statue in easy and comfort way without moving and going to the source, and each bottom have the explanation for the function.
2	 Fig.10. Perceptible information- remote control & First aid box	The design communicates necessary information effectively to the user, regardless of ambient conditions or the user's sensory abilities. The fourth principle states the importance of having the information necessary to understand and communicate the information, whether in words or symbols.
No.	**Universal Design Principle in Residential Spaces**	
	Principle 5:	**Tolerance for Error-Findings**
1	 Fig.11. Tolerance for Error - water dispenser	Water dispenser: As shown in the picture, it contains information and pictures showing where the cold and hot water are and shown in colors.
2	 Fig.12. Tolerance for Error - Windows	(Windows) it is especially important to have a fence in the residential buildings for the safety of children.
3	 Fig.13. Tolerance for Error - stairs	(Stairs) there is two stairs one inside and one outside it is very useful for emergency exit or if you have a separate apartment it will be more privacy to them if they have guests without discomfortable the rest of the home persons.
4	 Fig.14. Tolerance for error - First aid box	The design minimizes hazards and the adverse consequences of accidental or unintended actions. As shown in the picture (47), the presence of first aid in the event of a dangerous situation. There are also sufficient exits to empty the house with the presence of hot extinguishers, and this applies this principle

No.	Universal Design Principle in Residential Spaces	
	Principle 6:	**Low Physical Effort- Findings**
1	 Fig.15. Low Physical Effort- Bathroom handle	(Bathroom handle) in guest bathroom there is a handle for the old persons or special cases persons.
2	 Fig.16. Low Physical Effort- closet	(closet) Here in the closet, it is not suitable to reach the top shelf. It takes effort to reach it, and the user has to change her body position to reach it.
3	 Fig . 17 . Low Physical Effort – kitchen work triangle	The design can be used efficiently and comfortably and with a minimum of fatigue. The sixth principle stipulates less effort, for example in the kitchen , which is arranging the sink, oven, and refrigerator in the shape of a triangle. Also, placing doors, windows, etc., so that using them does not require much effort, But I noticed that the stairs in our house require a lot of effort to climb because they were built in a very steep way.
No.	**Universal Design Principle in Residential Spaces**	
	Principle 7:	**Size and Space for Approach & Use- Findings**
1	 Fig.18. Size and Space for Approach & Use - kitchen	(Kitchen) L-shape design it is very long and small space for moving to a lot of persons, not recommended.
2	 Fig.19. Size and Space for Approach & Use - Remote control handle	(Remote control handle) it is in the wall with the other switches of the room, easy to approach and simple just pull it to up.
	  Fig.20. Size and Space for Approach and Use -stairs	Appropriate size and space are provided for approach, reach, manipulation, and use regardless of user's body size, posture, or mobility. The last principle states that there is sufficient space for movement, and I noticed that the staircase in our house is very narrow, which leads to difficulty in moving furniture from one floor to another.

Educational Space- Following the case study analysis conducted from the residential spaces, Gulf university campus was selected as the next case study. The findings are listed in the table below. (Table 2)

TABLE 2: UNIVERSAL DESIGN PRINCIPLES IN EDUCATIONAL SPACES

No.	Universal Design Principle in Educational Spaces	
	Principle 1:	**Equitable Use- Findings**
1	 Fig. 21. Equitable use- ramps	(Ramps) There is ramp for the wheelchair in the all sections of the campus, main building door, cafeteria, studio, labs, etc.
2	 Fig . 22 . Equitable use- toilet	(Toilet) there is a separate toilet for the special cases.
No.	**Universal Design Principle in Educational Spaces**	
	Principle 2:	**Flexibility in Use- Findings**
1	 Fig . 23 .flexibility in Use- Automatic door	(Automatic door) After the inter door there is an automatic door that we didn't use I think if we remove it will be better and more flexible to the user to not be clash its stuff and the door and there is no sign for it, it is for only the employee.
2		(Nurse room) there is ramps for the nurse room it is more functional for emergency, the wheelchair or the Nursing Care Bed.

No.	Universal Design Principle in Educational Spaces	
	Principle 1:	**Equitable Use- Findings**
	Fig.24.Equitable use- Nurse room	
No.	**Universal Design Principle in Educational Spaces**	
	Principle 3:	**Simple and Intuitive Use- Findings**
1	 Fig . 25 . Simple and Intuitive Us- Elevato	(Elevator)It is not easy to understand where the elevator is, it is hidden with a lot of doors with no sign and if there is any emergency on the elevator no body will hear them
2	 Fig . 26 . Simple and IntuitiveUse- Dispense	(Dispenser) there is in each floor dispenser with cups and trash, being all of them in one place and close to each other make it intuitive for the user.
3	 Fig . 27 . Simple and Intuitive Use – first aid	first AID- it is easy to understand it is first aid to the user.
No.	**Universal Design Principle in Educational Spaces**	
	Principle 4:	**Perceptible Information- Findings**
1	 Fig28. Perceptible Informatio - Cafeteria and Elevator	(Cafeteria and Elevator)There is no enough symbols for example the cafeteria and the elevator student don't know where it is because there is no sign.
2	 Fig.29. Perceptible Information - Fire extinguishe	(Fire extinguisher) there is in every floor this in a clear and safe place for fire extinguisher with a sign.
3	 Fig. 30 . Equitable use- Emergency exit	(Exit sign / emergency exit) there is everywhere the sign, it is clear to see it with the green color that is related to safety and 'go' or red color which is related to "warning"

No.	Universal Design Principle in Educational Spaces	
	Principle 1:	**Equitable Use- Findings**
4	 Fig. 31 . Equitable use- Recycling boxe	(Recycling boxes) it is clear to reach the point that you want because of the signs and colors.
No.	**Universal Design Principle in Educational Spaces**	
	Principle 5:	**Tolerance for Error- Findings**
1	 Fig. 33 . Tolerance for Error- Elevator bottom	(Elevator bottoms) we can clearly use it with just pressing the bottom it is simple and there is a ring bottom that refer to emergency and there is a phone to contact with the people from outside.
2	 Fig 34. Tolerance for Error- CCTV Syste	(CCTV System) there is a room for CCTV System that shows for us what the cameras take, which it is so helpful for misunderstand and prejudgment for example the stealing case.
3	 Fig.35. Equitable use – main building door	(Main building door) it is butter if the main door is sliding it will be not hard specially with engineering students, they care a lot of stuffs or the people using a wheelchair it is hard to them with manual door.
4	 Fig36. Equitable use –Sensors	The design can be used efficiently, comfortably and with less fatigue. The sixth principle states less effort, and it is likely that all public places will apply this principle. In this university, this principle has been applied, especially in bathrooms, where the sensing feature is in many things, including the lamp, as soon as a person enters, it lights up and after he leaves, it turns off, which leads to saving electricity, as well as the water tap and soap dispenser, as soon as the hand is placed, the tap releases water, and as soon as the hand moves away from the sensor, the water stops, which helps to conserve water and not waste it, as well as the presence of a heat sensor in the event of a fire, it senses the presence of heat and smoke, it emits a sound to alert, and some of them release water to stop the fire.
No.	**Universal Design Principle in Educational Spaces**	
	Principle 6:	**Low Physical Effort- Findings**

No.	Universal Design Principle in Educational Spaces	
	Principle 1:	**Equitable Use- Findings**
1	 Fig37 . Low Physical Effor - shelf	(shelf) in the picture, it requires effort for me to reach the top shelf to pick up a book.
2	 Fig38 . Low Physical Effor - Remote holder	the disabled require great effort to reach a remote, and this requires them to change their normal body position to reach and get what they want.
No.	**Universal Design Principle in Educational Spaces**	
	Principle 7:	**Size and Space for Approach & Use- Findings**
1	 Fig 39. Size and Space in Restroom	The measurements of the restroom it is fit with human body but not the human factors, there is no space for moving in the toilet it should be bigger.
2	 Fig 40. Size and Space in public space	(Tennis table) the place that they put the tennis table is wrong it is a corridorit that people walk on, and the ball could hit them.
3	 Fig 41. Size and Space in staircase	(Stairs) the size of steps not equally it could make persons fall it must be equally.
4	 Fig 41. Size and Space in classroom	(chairs), there is no distance between the two chairs, which leads to a collision

Discission:

In the conducted case studies, it is observed that some of the principles are considered, while others are not. In residential buildings, it is essential to have protective barriers on all windows for the safety of children, which are present; however, there is no ramp provision. The necessity for ramps extends beyond accommodating elderly individuals to include those with temporary injuries, such as fractured limbs. It is determined that services must be provided equitably for all. In the university building, ramps are available in all sections, facilitating access for individuals with special needs. However, the doors are not easily accessible to them as they are not equipped with automatic sensors for opening and closing. It is concluded that the installation of automatic doors is necessary to enhance functionality for these individuals. It is crucial to adhere to the seven principles of universal design to provide equitable service to all people. These principles include flexibility in use to accommodate various body sizes, simple and intuitive functionality that is easy to comprehend, and the provision of information through symbols, words, and colors to enhance focus. It is important to consider tolerance for errors, given the uncertain nature of the future, necessitating measures to prevent serious issues. Low physical effort is also significant in any building to enable efficient task completion without disruption. It is essential to design spaces with appropriate dimensions that align with human body proportions and ergonomic factors, considering both dynamic and static postures to ensure proper approach and utilization.

Conclusion:

Bahrain is making progress in implementing Universal Design principles in residential and educational settings; however, further advancements are possible. While the public sector and new construction are demonstrating improvements, older buildings and some educational institutions still lack comprehensive accessibility. To create a truly inclusive society, Bahrain must implement more stringent legislation, enhance public awareness, and ensure consistent application of Universal Design across all domains. Only through these measures can Bahrain ensure that all its citizens, regardless of their abilities, are able to fully participate in the social and educational aspects of the nation.

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