PROCEEDINGS OF ASIA DESIGN AND INNOVATION CONFERENCE
20–21 NOVEMBER, 2025, SHANGHAI, CHINA

INTEGRATED ACTIVITY AND SPACE DESIGN APPROACH FOR CHILDREN PLAYGROUND

Yiwen WANG, Yong Se KIM
Tongji University, China

ABSTRACT
Children's play activities are characterized by spontaneity, immediacy, and high contextual dependency, yet current playground design often prioritizes aesthetics and functionality over behavioral needs. This study proposes an integrated activity and space design approach by incorporating the Context-Based Activity Modeling (CBAM) framework to systematically analyze the interplay between children's activities and spatial elements. Field observations were conducted in multiple community spaces so that the general applicability of CBAM as a framework is confirmed. The study reveals how physical structures and psychological contexts jointly shape children's play behaviors. The proposed integrated framework would contribute to building child-centered play environments.

Keywords: Child Play Activity, Public Space, Integrated Activity and Space Design

1 INTRODUCTION

1.1 Children Activities in Community Playground

With the advancement of urban modernization and the transformation of community spatial patterns, children's play environments have increasingly become a focal point of academic inquiry. Outdoor areas constitute a vital part of children's daily surroundings, exerting significant influence on their overall development. Well-planned outdoor playgrounds not only foster sensory–motor skill growth and cognitive engagement with the environment, but also promote richer social interactions as well as the cultivation of moral values and personal character [1].

However, the design of children's activity spaces encompasses multiple complex considerations. On the one hand, developmental goals vary across different stages of childhood, spanning physiological, cognitive, social, and emotional domains [2], [3], [4]. With the transformation of daily activity spaces under the influence of urbanization and educational development, children's activities increasingly display immediacy, playfulness, and strong situational dependency. Their spontaneous and exploratory behaviors, coupled with creativity and vitality, drive children to constantly reinterpret and explore community spaces, thereby imposing higher demands on spatial design. Contemporary urban children's activities have thus undergone profound transformations. Community spaces, as the primary venues for such activities, now present greater diversity in both activity modalities and spatial utilization requirements.

1.2 Need for a Structured Approach for Children Play Space Design

Currently, there is still a lack of a systematic methodological framework for analyzing the interrelations of children–activity–environment. Without structured frameworks, it becomes difficult to uncover the complexity of children's changing spatial practices and to generate coherent design strategies. There exists an urgent need to develop structured approaches to spatial design that can better accommodate the dynamic nature of children activities [5].

On the one hand, many efforts on child spatial design have failed to adequately incorporate a child-centered perspective [6]. Although these designs often place strong emphasis on visual aesthetics, safety standards, and proportional scaling, they frequently neglect children's intrinsic activity patterns and spatial autonomy. This disconnection is largely due to the lack of systematic observation and analysis of children's actual behaviors, which results in a prioritization of spatial diversity in display forms rather than providing effective behavioral support. As a consequence, children are reduced to passive

users instead of active participants, undermining both their sense of agency and the developmental potential of the space. Designs that lack structured methodologies struggle to accommodate the complex and evolving needs of children.
On the other hand, while community spaces function as the primary venues for children's daily activities, they are characterized by heightened diversity in both activity modalities and spatial utilization. In contrast, designated and isolated playgrounds often fail to fully meet children's needs. Research has shown that children demonstrate a stronger preference for informal play environments, such as streets, alleys, or transitional zones within neighborhoods [7]. These are non-specialized public areas not originally intended for play—such as local street segments, leisure paths, and commuting routes—yet children consistently engage in more active physical play, spontaneous exploration, and independent activities in such spaces [8]. The organic patterns of use in these informal environments stand in sharp contrast to the more rigid frameworks of traditional playgrounds, offering more authentic insight into children's true spatial preferences and behavioral needs.

1.3 Integrated Activity and Space Design Approach

Many existing space design models place their primary emphasis on spatial structures and functions [9], but pay insufficient attention to the specific activities for which these spaces are intended. A notable attempt to integrate activities and spatial arrangements can be found in the Activity–Space Ontology [9]. Their framework employs hierarchical representations of activities and spatial elements, making explicit the relationships between activities, the resulting spatial configurations, and supporting structures such as equipment. However, this ontology remains limited in several ways. First, it largely captures activity at the task level, without detailing the nuanced and dynamic relations between actor, activity, and context. Second, it does not fully accommodate subjective dimensions such as actor experience, psychological states, and contextual value. Consequently, the Activity – Space Ontology falls short of supporting space design strategies that engage with children's spontaneity, exploration, and psychological needs.
The Context-Based Activity Modeling (CBAM) method has been proposed an integrated activity and space design approach for children's play space design using a case of community space [10]. CBAM describes human activities formally using Actor, Action Verb, Object, Tool, Goal, Relevant Structure, Physical and Psychological Context [11], [12], thereby creating a structured and detailed integrated representation of behavioral elements and structural elements, including space structures. Compared to Activity–Space Ontology, CBAM not only highlights the physical and structural conditions of space but also incorporates children's behavioral autonomy, emotional states, and safety concerns into the representation.
This paper presents multiple cases of community spaces where CBAM demonstrated its potential as an integrated activity and space design approach for children play space design. The CBAM method would allow designers to more effectively observe, record, and interpret the interrelations among activities, actors, and environments. This would enable identification of design strategies that respond both to children's physical play demands and to their psychological and social development needs, thus bridging the gap between behavioral observation and spatial design practice.

2 METHODOLOGY

2.1 Context-Based Activity Modeling (CBAM) Method

Context-Based Activity Modeling (CBAM) is a schematic framework designed to structure the relationship between human activities and their contexts [11], [12]. Originally developed for service design [11], [12], CBAM has since been extended to multiple design domains, including design for affordances [13], design process representation [14], emotional and experiential data analysis [15], and cognitive exercises for design thinking [16]. At its core, CBAM highlights that all activities are inherently shaped by contextual factors, and thus context information must be specified in a structured and comprehensive way.
The basic part of the activity description is the action verb. The object of the action is the object of the activity. Three different actors are involved; the activity is conducted by the active actor. In some cases, the activity may have the passive actor and/or the third-party actor as well. The tool can be used in conducting the activity and is specified if needed. The object and the tool are further described with their

properties. The activity description is completed with context elements. The context is described by four types of context elements. The goal context represents the objective of the activity. It can be represented by another activity for which the present activity is conducted, often beforehand. Sometimes, the goal may also represent values the present activity is to pursue. The relevant structures include structural entities related with the object and the tool in performing the activity. The physical context includes time, place, and other various environmental information such as lighting condition and weather condition. Note that the physical context information can be obtained from various sensors [11]. The psychological context has been expanded from the initial social context of an ISO definition [17] of contexts to represent diverse emotional experiences of the active actor. Actor emotion experiences could be represented with actor subjective evaluations as in the case of [18] or with observer evaluations. The social context represents whether the activity is conducted in public or in private. Also, whether the activity is conducted alone or together with other actors can be represented. Note that the CBAM method has been made by combining the activity theory [19] and the ISO definition of contexts [17] with some extension to address psychological contexts. That is, the activity is described such that “the active actor conducts the action of the action verb on the object using the tool (to the passive actor) under the context composed of the goal, the relevant structure, the physical context and the psychological context elements” [12]. Understanding the relationship between these context elements and observable activity sequences is key to understanding spatial activities and formulating effective design strategies. Note that rich context information represented in the CBAM method is a significant advantage of CBAM over the Activity－Space ontology. While equipment element is the only structure element is the Activity－Space ontology’s activity representation, objects, tools, and relevant structures all can address space structural elements in CBAM. This also makes CBAM much more powerful in representing diverse various space structural elements tightly associated with a corresponding activity. Through the analysis of context, actor, tool, object and other elements, children’s activities and related spatial design structures are intuitively associated and analyzed, and a direct translation model is established to provide methodological support for children's spatial research [10].

2.2 Application of the CBAM Framework

In the field of children's activity-space research, previous attempts, such as the project have used the CBAM framework to decompose the sandbag throwing game into five activity levels, revealing the correspondence between game behavior and spatial structure [10]. However, these studies have mainly focused on a single activity type and have not fully examined the coexistence and interaction relationships of multiple activity categories in the same spatial environment, as well as the diversified and dynamic use of spatial elements in different activities. In this study, a further analysis of more diverse activities has been conducted, and a comparative discussion has been made with the sandbag throwing case, summarizing a better CBAM method combined with the theoretical system of children's activities and spatial design.

Building on existing research, this study further explores the systematic integration of the CBAM framework into the research and design of children’s community spaces. Specifically, it analyzes design cases of community spaces for high-frequency children’s activities selected under the activity modeling framework of CBAM. By observing and documenting diverse activities across two community spaces, the study applies CBAM to reveal how spatial elements—such as shading structures, ground materials, and boundary delineations—shape behavioral patterns within specific activities. Through field observation and multi-case comparison, several representative children’s activities are identified and examined, with the CBAM framework employed to analyze the interaction mechanisms between behavioral structures and environmental factors. On this basis, spatial design strategies are proposed.

The CBAM modeling method is applied through the multidimensional decomposition of activity elements. The framework is structured around five key dimensions: Actor, Tool, Object, Relevant Structure, and Physical and Psychological Context. By systematically analyzing these dimensions, this study uncovers the behavioral patterns, spatial elements, and interaction mechanisms that shape children’s activities in specific community contexts. For this research, several representative activities were selected from two community courtyards, encompassing different activity categories: Sandbag throwing (activity Throw and Chase), Sitting and riding under lighting projection (activity Sit and Ride) and Skateboard sliding game (activity Slide).

CBAM enables both multi-angle analysis of individual activities and comparative analysis across different activities. This dual capacity helps designers to generate targeted design insights for specific activity spaces, while also expanding design perspectives in more flexible and complex activity environments. The analysis of these two case studies demonstrates that, on the one hand, the same type of activity within a space can be systematically deconstructed by CBAM to yield concrete design strategies; on the other hand, the coexistence of different activities in the same space provides designers with new considerations for spatial creation and integration.

3 CASE STUDIES AND RESULTS

3.1 Case 1: Sandbag Game in Community 1

In Community 1, the sandbag game takes place in a central courtyard of a residential compound in Chongqing, characterized by limited facilities but frequent children's activities. Using time-lapse photography, fixed-point observation, and activity categorization [5], the study documented children's spontaneous behaviors. Despite spatial constraints, the site supports diverse interactions and psychological states. The sandbag game was selected as a representative case because of its relatively simple rules and actions, which facilitate clear activity deconstruction and relational analysis [10]. At the same time, its high levels of excitement and playfulness provide valuable insights into the behavioral patterns of children in community play spaces. The game involves multiple sequential and overlapping activities, including throw, run, chase, hide, seek, and seize. These actions generate a spontaneous and dynamic form of play in a space that was not originally designed for this purpose. Through CBAM, these activities are systematically analyzed to propose structured and sustainable spatial design strategies. This study highlights the importance of analyzing the direct relationships among actors, activities, and relevant structures, with particular attention to micro-actions and low-frequency actions. The analysis focuses on relevant structures and physical-psychological contexts, in order to generate structured and sustainable design strategies for children's play spaces.

3.1.1 Analysis of the Activity Throw in Sandbag Game

In this section, activity throw will be described in detail through the CBAM lens. The analysis particularly emphasizes background elements — such as relevant structures and physical and psychological contexts—since these are critical to understanding and improving the design of children's play spaces.

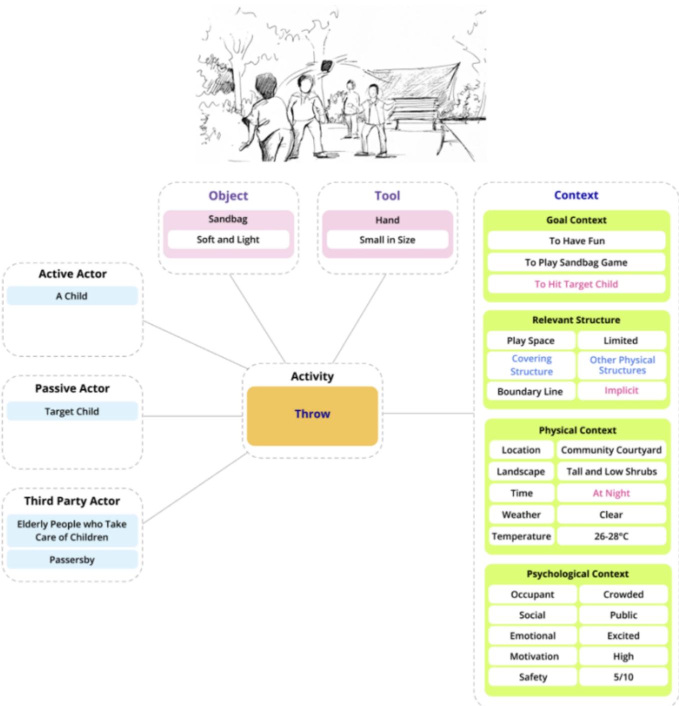

Figure 1. CBAM Description of the Activity Throw (from [10]).

1. Actors, Object and Tool

As the core initiating activity in the sandbag game, the activity *throw* marks the beginning of a sequence of actions, which is shown in Figure 1. The active actor is the child acting as the thrower, who uses the hand as the tool to propel the sandbag (object) toward a target in the opposing group. The passive actor is the target child, while third-party actors include elderly caregivers and passersby, who monitor the game to ensure safety. The small size of the child's hand influences grip and throwing technique, while the sandbag's light weight and soft texture shape the dynamics of the throw. Note that these properties of the object and the tool are described as parts of the descriptions of the object and the tool respectively as shown in Figure 1.

2. Goal Context

The goal contexts of the activity *throw* are threefold: to have fun, to play sandbag game and to hit the target child.

3. Relevant Structure

The relevant structures are the play space, the covering structure and boundary line. The play area is limited, suggesting that the available space may lead to increased risks of collisions between participants. Other physical structures, like low shrubs and benches. The boundaries of the activity are often implicitly defined, relying on ground gaps, tile counts, or surrounding net-like structures. Unlike formal playgrounds or school settings where boundaries are explicit, these ambiguous boundaries may increase safety risks during play.

4. Physical Context and Psychological Context

The physical context that influences activity *throw* includes location, landscape, time, weather and temperature. The activity takes place in the community square at night, with clear weather and temperatures ranging from 26 to 28 °C. Note that the time is at night as shown in Figure 1. Low visibility at night increases the challenge for target children to evade throws, while light wind may alter sandbag trajectories. Psychologically, the thrower is typically in a state of high motivation and excitement, which may lead to more aggressive throwing patterns. This structured analysis contributes to spatial design, game design, child activity research, and safety strategy development.

3.1.2 Analysis of the Activity Chase in Sandbag Game

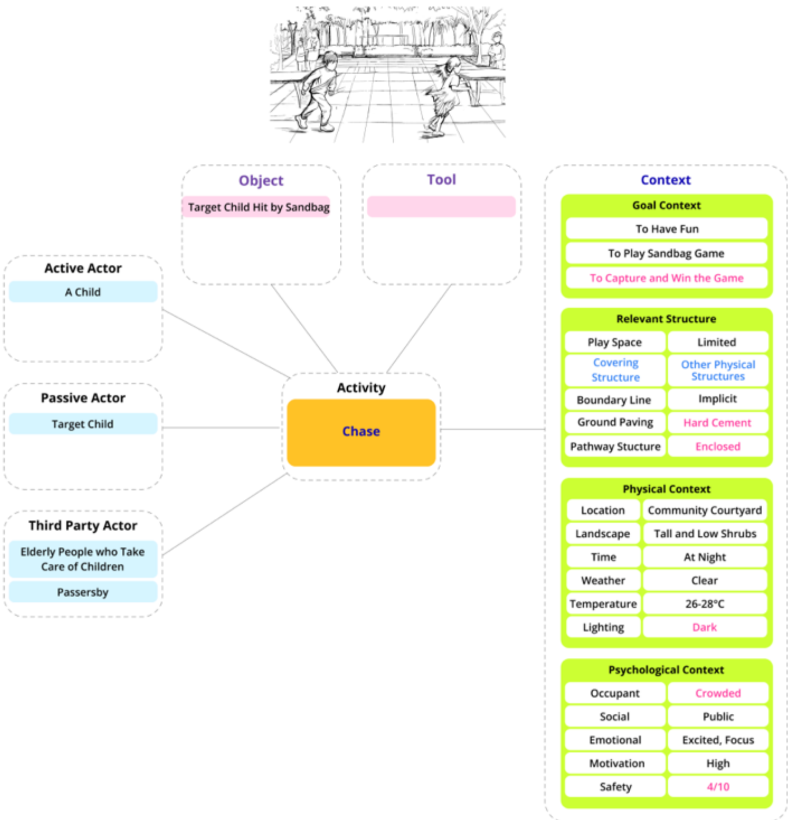

Figure 3. CBAM Description of the Activity Chase (from [10]).

1. Actors and Object

In the CBAM description of the activity chase shown in Figure 5, different actors play distinct roles are identified: the child who is chasing in the game is the active actor, while the target child being pursued is the passive actor. Elderly people who take care of the children and passersby as the third party actors, are not directly involved but influence safety and supervision. The object is the target child hit by the sandbag, highlighting the interactive and sequential nature of the sandbag game.

2. Goal Context

There are three goals in the activity *chase*: to have fun, to play sandbag game and to capture and win.

3. Relevant Structure

The relevant structures encompass the play space, covering elements, boundary lines, ground paving and pathway structure. The play space is limited. Covering structure are other physical structures, like low shrubs and benches, can add fun elements but may also serve as potential obstacles, affecting the activity. Boundary line refers to implicit boundaries, such as those implicitly defined by shrubs, fences, or road edges, may limit the chasing area and create potential collision hazards. Ground paving is hard cement surfaces which may elevate injury risks during falls. Pathway structure is enclosed pathways which support more orderly chasing and reduce slipping risks.

4. Physical Context and Psychological Context

The activity *chase* takes place in a community courtyard, typically at night. Tall and low shrubs constrain visibility, while poor lighting increases accident risks same as in the activity *thow*. Notably, tall and low shrubs may affect visibility and influence the chasing route, while poor lighting increases accident risks. Psychologically, crowded environments suggest a higher risk of collisions. As the game occurs in a public space, external distractions may also affect children's focus. During the chase, children are typically excited and highly focused, with strong motivation to compete. However, the safety score is only 4 out of 10, as risks arise from hard ground, limited space, and poor lighting, which may result in falls, collisions, or injuries.

3.1.3 Design strategy from CBAM analysis of Activity Throw and Chase

First, improve ground surface materials and impact buffering. The quality of ground surfaces is a critical factor affecting children's activities, as shown in the relevant structure of sandbag play (Figures 1 – 2). During high-speed activities such as running and chasing, hard surfaces pose considerable safety risks, reflected in the CBAM description with a safety level of 4 out of 10. To address this, ground materials should be chosen for elasticity, anti-slip properties, and friction, providing cushioning to reduce falls. Safer alternatives include rubber granules, turf, EVA foam, or sand. In addition, impact-buffering zones or soft wrapping near turning points and obstacles can further reduce injury risks. Beyond safety, colorful surface patterns and micro-topographies may also enrich sensory experiences and motivate physical engagement.

Secondly, define explicit and implicit boundaries in play spaces. In the context of play activities of the sandbag game case, boundary lines emerge as a frequently referenced relevant structure within the CBAM framework. Often implicit, children mark limits through floor tile patterns, vegetation, or safety nets. Such ambiguity has dual effects: it enables flexible rule-making and imaginative play, but also increases randomness and safety risks. In design practice, boundaries should reflect site conditions and children's behavioral needs. Rather than relying on rigid fences or painted lines, it is more effective to create flexible, engaging, and safety-conscious “activity boundaries”. These may be created with contrasting materials, guiding lights, or subtle markers, enhancing both imaginative play and spatial safety, thus ensuring a more organized and secure environment.

Thirdly, integrate flexible and dynamic lighting design. As revealed through the physical context element, children are active at night. However, lighting conditions at night are relatively lacking, though it is a critical physical context element in both activities *throw* and *chase*. It should be noted that some psychological context elements like excitement may also be related in a way that a little darkness of lighting context element may rather enrich their values. Given the frequency of nighttime activities and the limitations of ambient lighting, it is recommended to incorporate dynamic lighting systems that provide adaptable illumination without compromising the immersive atmosphere of play. Options include motion-sensor lights, low-level pathway lighting, and interactive glowing installations, which enhance both safety and immersion [10]. Options include motion-sensor lights, low-level pathway lighting, and interactive glowing installations, which enhance both safety and immersion.

3.2 Case 2: Lighting Projection in Community 2

The case of activities around lighting projection focuses on a community courtyard characterized by frequent nighttime activities and specific lighting conditions. By applying the CBAM framework, children's activities under the lighting projection scenario (such as sit and ride) are analyzed to reveal how light and shadow construct spatial boundaries and create a sense of temporary place-making.

3.2.1 Activity Sit (around Lighting Projection)

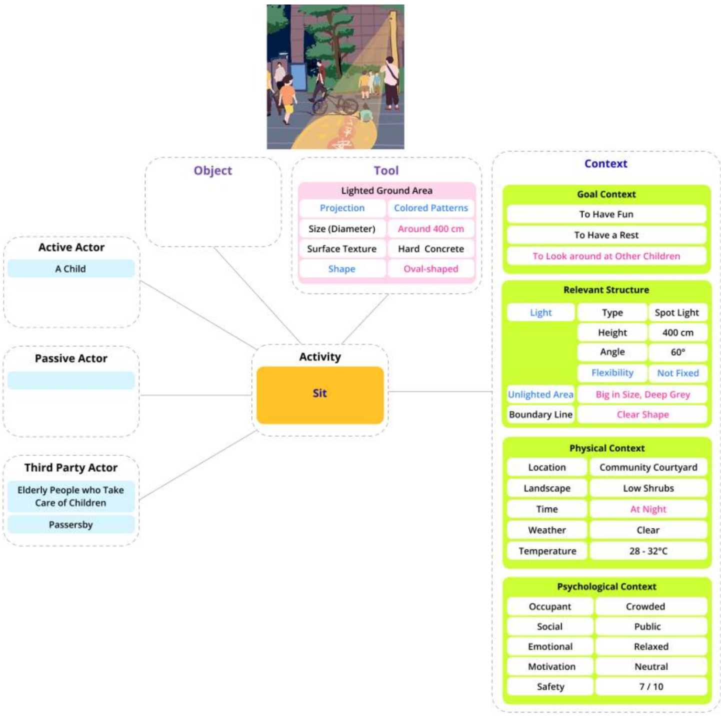

Figure 4. CBAM Description of the Activity Sit (from [10]).

1. Actor and Tool

In the CBAM description of the activity *sit* (around the Lighting Projection) shown in Figure 4, the active actor is a child sitting within the lighted ground area, while third-party actors include elderly people who take care of children and passersby. The tool is the lighted ground area, which the child interprets as a visually appealing, clearly bounded temporary "game stage." The lighting projection produces colored patterns, with a circular shape, a flat, hard-concrete surface, and distinct edges created by light and shadow.

2. Goal Context

The goal context is to have fun, to have a rest, and to look around at other children

3. Relevant Structure

Light, which is a spotlight, positioned at a height of approximately 400 cm and angled at around 60°, produces a strong contrast between the brightly lit central circle and the surrounding dark-gray unlit areas. The lighted ground acts as a natural focal point, while the unlit areas create implicit spatial boundaries. Unlighted Area is big in size and deep grey in color. Thirdly, the boundary line is oval with a clear shape, which limits the range of children's sitting.

4. Physical Context and Psychological Context

Physically, the activity *sit* occurs together with the above activities, thus its location, landscape, and time are same as the activities of sit in Figure 1. As the temperature is 28 – 32°C, which is relatively high, the ground surface consequently remains warm. Psychologically, the space is relatively crowded and public. The actor's emotional state is relaxed, with neutral motivation primarily oriented toward rest and observation. Safety is rated 7 out of 10, the main risks stem from potential bumps against hard surfaces and insufficient lighting in the peripheral areas.

3.2.2 Activity Ride (along Lighting Projection)

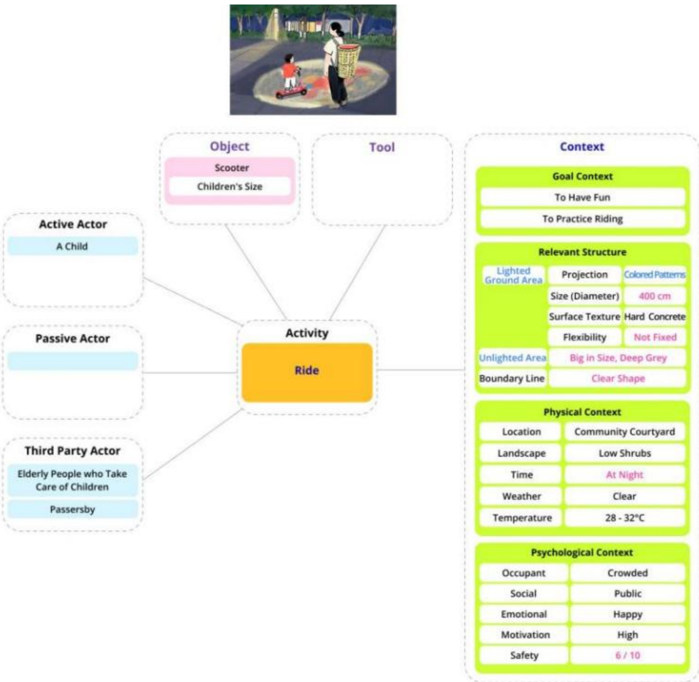

Figure 5. CBAM Description of the Activity Ride (from [10]).

1. Actor, Tool and Goal

The child riding the scooter is the active actor, while the third party actors include elderly people who take care of children and passersby. The scooter designed in a children's size, functions as a core riding tool, providing the child with mobility and entertainment functions, and its small size is suitable for activities in limited spaces.

2. Goal Context

In the activity *ride*, the goal contexts are to have fun and to practice riding.

3. Relevant Structure

It consists of three key elements. The lighted ground area, functioning as the primary activity interface, features the projection of colored patterns that creates a dynamic and visually engaging path, where shifting light and shadow simulate a playful riding track. It has good flexibility. In contrast, the unlighted area is big in size and deep grey in color. As for the boundary line, the distinction between the lighted and unlighted areas produces a visible boundary line with a clear shape. This demarcation provides spatial orientation and creates a gamified sense of challenge, stimulating behaviors such as detouring and path-following.

4. Physical Context and Psychological Context

Physical context of the activity ride is the same as the activity sit in Figure 4. The overall environment provides suitable conditions for outdoor activities at night, but lighting mainly relies on artificial projection sources. Psychologically, the occupant of this space is crowded, and the social context field is public, with children showing a happy emotional state and high motivation. Safety is rated 6 out of 10, which is generally average, with the main risks coming from possible collisions and loss of control during night riding, as well as interference caused by high pedestrian traffic in public spaces.

3.2.3 Design Strategy – Light as a Track

Overall, the concentrated light projection establishes a striking yet temporary interactive focus within the courtyard. It satisfies children’s needs for exploration and rest, while simultaneously providing caregivers and passersby with favorable conditions for observation and supervision. Additionally, the interaction between the projected light area and children’s riding behaviors transforms the community courtyard into a temporary yet engaging play environment. The light-shadow boundary not only directs children’s riding paths but also gamifies the activity ride. From above it can be conducted that clear light projections can not only overlap as surface structures above the ground but also as linear structures to divide the dark and light areas. In cases with sufficient area, the availability of tracks and signage is possible. Thus, for activities such as skateboarding, cycling, or scooter riding, light-based contours can better define boundaries and activity categories. Using light as a clean, flexible, and adaptable spatial structure allows designers to activate otherwise limited spaces, offering both clarity of movement and imaginative potential.

3.3 Case 3: Skateboard Sliding Game

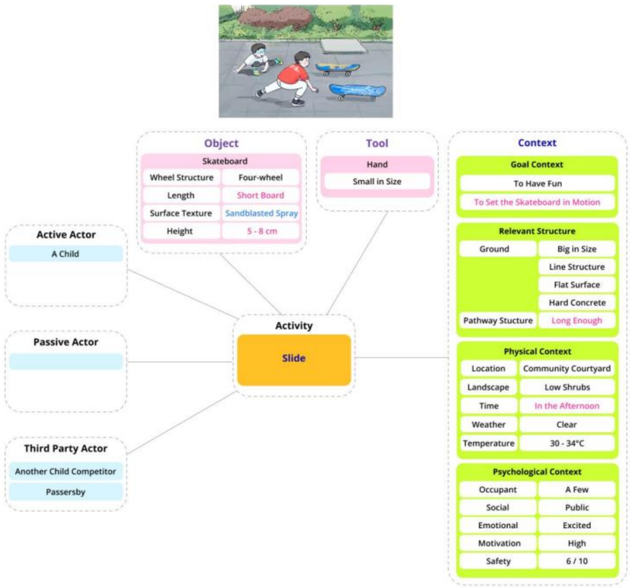

Figure 5. CBAM Description of the Activity Slide (from [10]).

1. Actor, Object and Tool

In the activity *slide*, the active actor is a child, while third-party actors include another child competitor and passersby. The skateboard serves as the object, with a four-wheel structure, short-board type, and a sandblasted surface designed to enhance grip and stability. The tool is the child's hand, which is used to push and to release the skateboard.

2. Goal Context

The goal contexts are to have fun and to set the skateboard in motion.

3. Relevant Structure

The ground is big in size with a line structure on it. Due to the hard concrete texture and its flat surface, it provides both stability and sufficient friction during the activity slide. The pathway structure is long enough to allow the skateboard a continuous sliding distance, which supports sustained play. This creates new affordances of speed, distance, and competition. The ground's flatness and pathway length become key spatial elements supporting this activity, showing how environmental structures extend the possibilities of play.

4. Physical Context and Psychological Context

Physically, the activity takes place in the community courtyard during the afternoon under clear weather, with temperatures between 30 – 34℃. The courtyard includes low shrubs, adding spatial enclosure but still leaving open paths for sliding. Psychologically, in terms of psychological context, the activity is public, and children experience excitement and high motivation. The safety level is moderate (6 out of 10) due to risks of falling, collisions, or skin abrasions caused by friction with the concrete ground.

3.3.2 Design Strategies: Reconsideration of Ground Detail Design and Relative Relationships

Through CBAM analysis designer should pay attention to the ground design. Ground is not merely a passive backdrop but an active trigger of spatial behavior. In skateboard sliding activities, children reinterpret the slab base and surrounding ground surface, transforming height differences and geometric configurations into new functional and symbolic roles. Variations in elevation, edge sharpness, and slope angle directly affect speed, safety, and playability. For designers, this suggests that ground details—height, geometry, and edge conditions—must be deliberately incorporated into behavior prediction and design considerations. Properly designed, they provide both behavioral affordances and safety support. Ground is not merely a passive backdrop but an active trigger of spatial behavior. Children's reinterpretation of the slab base shows how surface qualities—height, materiality, and boundary conditions—can be redefined into new functional and symbolic roles. For designers, this highlights the necessity of carefully integrating ground characteristics into child-centered spatial design, ensuring both behavioral affordance and safety support.

Additionally, the texture and color of ground surfaces are equally significant. A grid-like net structure, combined with rectangular patterns and color mixing, can create hidden game boundaries and implicit rule lines. For example, colored stripes can guide sliding direction, while textured surfaces provide both friction control and visual cues. These subtle design elements not only enrich sensory experiences but also embed rules and affordances into the play environment without rigid constraints.

4 DISCUSSION

4.1 Focusing on Activity-Centered Design Framework through CBAM

The analysis shows that children's activities directly inform spatial design and renewal. Compared with the traditional Activity/Space ontology—which only lists factors such as performer, consumer, and equipment—CBAM provides a more structured and explicit description of activities. It distinguishes clearly between Actor, Tool, Object, Goal Context, Relevant Structure, Physical Context, and Psychological Context, thereby uncovering implicit relationships between activities and spatial elements. This structured breakdown enables designers to better understand behavior–environment interactions. Importantly, the inclusion of psychological contexts (e.g., safety, emotion, motivation) allows both researcher observations and potential child feedback to be incorporated, offering a more authentic representation of user experience.

4.2 CBAM Enables Accommodating Experience of Child Actors in Play Space Design

CBAM offers significant methodological value for connecting children's behavioral patterns with spatial and structural elements in a systematic way. This enables designers to propose targeted and generalizable design strategies—for example, regarding ground surface materials, lighting systems, or activity boundaries. Unlike conventional approaches focused on function or aesthetics, CBAM emphasizes context–behavior–environment logic, enhancing spaces' behavioral supportiveness. This method not only produces strategies specific to certain contexts but also abstracts transferable design principles applicable to a wider range of scenarios. Furthermore, the structured accumulation of CBAM-based analyses helps build a design repository for children's spaces. Such a repository allows strategies derived from one set of activities to be reused in similar spaces or activity types, improving both design efficiency and adaptability.

4.3 CBAM Reflects Real-time Feelings and Dynamic Needs of Child Actors

The psychological context element of CBAM (including safety, sense of security, motivation, and emotion) enables the integration of children's subjective experiences and dynamic needs into the design process. This makes CBAM a framework capable of responding to social, experiential, and developmental dimensions of children's play. The representation of psychological contexts can be diverse: it may rely on researcher observations, but it can also be complemented by real-time subjective feedback from children through in-situ surveys or dynamic experience evaluations [18]. By doing so, design improvements can better reflect children's actual feelings and evolving needs.

5 CONCLUSION

This study applied the CBAM method to systematically analyze children's activity cases—including sandbag throwing game (throw and chase), activities under lighting projections (sit and ride), and skateboard-related activity (slide)—within two different community courtyards. By decomposing these activities into elements of actor, tool, object, relevant structure, physical context, and psychological context, the study demonstrated that children's play is not only shaped by spatial and structural conditions but also dynamically redefines the affordances of ordinary community environments.

CBAM enables designers to transform knowledge of activities into structured spatial strategies. It supports activity-centered approaches for ground materials, spatial boundaries, lighting, and integration of static and dynamic zones. Compared with conventional function-centered methods [10], it also provides structured feedback on behavior–environment interactions, offering more child-centered, behaviorally responsive strategies. Accumulated CBAM analyses can form a design repository, facilitating knowledge reuse, transferability, and design efficiency. Children's changing needs and creativity can be better observed and transform though CBAM, being regarded as the subjects of real participation in space. Designers can use CBAM to structure and direct the design process. Through the structured analysis of CBAM, the presentation of activities and spatial relationships can provide more intuitive, clear and in-depth design strategies.

Based on CBAM analysis, the research proposed design strategies that address ground surface materials, spatial boundaries, lighting systems, and the integration of static and dynamic activity zones. Compared with conventional function-centered approaches, the CBAM framework offers more behaviorally responsive and child-centered design strategies. As a methodological contribution, this study demonstrates that CBAM can serve as a design framework for activity-centered playground and community space design. Additionally, the structured accumulation of CBAM-based activity analyses can gradually form a design repository, supporting knowledge reuse across similar spatial conditions and activity types. This repository not only facilitates the transferability of strategies but also enhances the efficiency and adaptability of child-friendly spatial design.

In the future, context-specific experience sampling and analysis (CESA) method with real-time actor evaluations in a subjective manner using digital tools [18] can be used for such evaluations. By combining structured activity modeling with participatory feedback, future studies can create more adaptive, safe, and stimulating environments. Ultimately, this research suggests that children's evolving needs demand a paradigm shift in design thinking: to regard them as active participants and co-creators of space, with CBAM offering a systematic pathway for linking activity observation, design strategy, and experiential validation. Toward this, a product-service systems [20] design approach, where human activities and product and space elements are systematically designed in an integrated manner, should be taken and integrated digital representation and interrogation systems would need to be developed as in the case of manufacturing servitization field.

REFERENCE

[1] Bao, Y., Gao, M., Luo, D., and Zhou, X. D. Effects of Children's Outdoor Physical Activity in the Urban Neighborhood Activity Space Environment. *Frontiers in public health*, vol. 9, 2021.

[2] Shaffer, D.R. Developmental Psychology: Childhood and Adolescence; Thomson Brooks/Cole Publishing Co.*: Eagle River,* WI, USA, 1996; pp. 79–85.

[3] Liu, Y.; Liu, J.; Xue, W. Design and implementation of interactive systems for intelligent architectures based on Piaget's cognitive development model. *Archit. Tech.* 2025, 31, 10–13.

[4] Renata, K.; Alves, G.H.; Rosa, P.J.D.; Fante, V.V.; Passos, F.F.D.; Fumagali, S.J.; Paz, F.R. Variability in Neurocognitive Performance: Age, Gender, and School-Related Differences in Children and from Ages 6 to 12. *Appl. Neuropsychol. Child* 2018, 7, 277–285.

[5] Wang, Y. A Study on Design Elements of Interactive Facilities in Public Spaces Based on Children's Play Behavior. *In Proceedings of the Asia Design and Innovation Conference (ADIC) 2024, Shanghai, China, 5–6 December 2024*; Design Society: Copenhagen, Denmark, 2024; pp. 467–476.

[6] Katsavounidou, G. Child, Play, and Urban Space: A Historical Overview and a Holistic Paradigm for Child-Centered Urbanism. J. Urban. Int. Res. Placemaking *Urban Sustain.* 2023, 16, 430–446.

[7] Gehl, J. Life Between Buildings: Using Public Space, 6th ed.; Translated by Jo Koch; *Island Press: Washington,* DC, USA, 2011.

[8] Hui, Y.; Liao, J.; Zhang, X.; Liu, Z. Child-Friendly Street Design Based on Behavioral Patterns. *Urban Plan.* Forum 2021, 92–99.

[9] Simoff, S.J.; Maher, M.L. Designing with the Activity/Space Ontology. In Artificial Intelligence in Design'98; Gero, J.S., Sudweeks, F., Eds.; *Springer: Dordrecht*, The Netherlands, 1998; pp. 23–43.

[10] Wang, Y.; Kim, Y.S. Child Play Activity Modeling for Playground Space Design Using the Context-Based Activity Modeling Method. *Sustainability* 2025, 17, 6244.

[11] Kim, Y.S.; Lee, S.W. Service Design for Product-Service Systems Using Context-Based Activity Modeling. *In Proceedings of the International Association of Societies of Design Research (IASDR) Conference*, Delft, The Netherlands, 31 October–4 November 2011.

[12] Kim, Y.S.; Jeong, J.; Hong, Y.; Hong, S. A Schema for Systematic Service Imagining: Context-Based Activity Modeling. *Sustainability* 2020, 12, 9558.

[13] Kim, Y.S. A Methodology of Design for Affordances using Affordance Feature Repositories. *AI Eng. Des. Anal. Manuf.* 2015, 29, 307–323.
[14] Kim, Y.S.; Lee, H. Process Characteristics of Product-Service Systems Development: Comparison of Seven Manufacturing Company Cases. J. Clean. Prod. 2021, 286, 124971.
[15] Kim, Y.S. Customer Experience Design for Smart Product-Service Systems Based on the Iterations of Experience–Evaluate–Engage Using Customer Experience Data. *Sustainability* 2023, 15, 686.
[16] Kim, Y.S. Cognitive Exercises for Design Thinking. *In Proceedings of the Asia Design and Innovation Conference (ADIC) 2024*, Shanghai, China, 5–6 December 2024; *Design Society: Copenhagen*, Denmark, 2024; pp. 296–304.
[17] ISO 20282-1; Ease of Operation of Everyday Products—Part 1: Design Requirements for Context of Use and User Characteristics. *ISO: Geneva,* Switzerland, 2006.
[18] Kim, Y.S.; Hong, Y.K. Systematic Method to Design Product-Service Systems Using Personalization Services based on Experience Evaluations. *Int. J. Prod. Dev.* 2019, 23, 353–385.
[19] Engeström, Y. Developmental Work Research: Expanding Activity Theory in Practice; *Lehmanns Media: Cologne*, Germany, 2005.
[20] Goedkoop, M.J.; van Halen, C.J.G.; te Riele, H.R.M.; Rommens, P.J.M. Product Service Systems, Ecological and Economic Basics; *The Dutch ministries of Environment (VROM) and Economic Affairs (EZ): Hague*, The Netherlands, 1999.