

Research Article

Research on the Design of Public Space Seating for Pregnant Women Based on the Concept of Accessibility

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Abstract

With the continuous enhancement of society's awareness of caring for vulnerable groups, barrier-free design in public landscape spaces has gradually become an important part of urban humanized construction. Pregnant women, as a special group, face many physical and psychological pressures during outdoor activities. Their rest behavior puts forward higher requirements for the safety, comfort and emotional support of public space seats. This paper takes "public space seats for pregnant women" as the research object, based on relevant regulations such as the "Standards for the Construction of Barrier-Free Environments", combined with user behavior observation and questionnaire surveys, analyzes the differences in the needs of women in different pregnancy stages in terms of age, physiological state, psychological changes, body proportions and other dimensions, and extracts five groups of key data for comparative analysis. On this basis, the FBS design method is used to systematically construct from the perspectives of function, behavior and structure, and further combines the TRIZ inventive problem-solving theory to identify the contradictions and conflicts in the design and propose innovative solutions. Through case analysis and design verification, this paper finally proposes a set of public space seat design schemes for pregnant women that take into account functionality, safety and emotionality, in order to provide empirical value and theoretical significance for barrier-free and human-oriented design in urban public facilities.

Keywords

Pregnant Women, Barrier-free, Public Space Seats, FBS Method, TRIZ Theory

1. Introduction

On May 31, 2021, the Political Bureau of the Central Committee of the Communist Party of China held a meeting to review the "Decision on Optimizing Fertility Policies to Promote Long-Term Balanced Population Development" and pointed out that in order to further optimize fertility policies [1], a policy allowing couples to have three children and

supporting measures would be implemented, and the level of services for prenatal care and child-rearing would be improved, as well as the development of a universal childcare service system. With the increasing need for social development and population structure optimization, enhancing the fertility willingness of women of childbearing age has become

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an important task in China's population strategy adjustment. Creating a safe and friendly environment for childbirth support is not only a manifestation of social progress and civilization but also a necessary support for ensuring the physical and mental health of pregnant women and promoting the construction of a fertility-friendly society.

The concept of barrier-free design is based on the "people-oriented" design philosophy and was first integrated into the field of architecture. Against the backdrop of the rapid expansion and renewal of high-density cities, the construction and renewal of urban outdoor environments also urgently need to transform, moving from the traditional focus on safety and comfort to meeting the needs of stress relief and health promotion. As an important means to achieve social equity and inclusiveness, barrier-free design has received increasing attention. In 2016, the "Healthy China 2030" Planning Outline proposed to promote barrier-free construction for vulnerable groups such as the disabled, pregnant women, children, and the elderly. With the full implementation of the two-child and multi-child policies in China and the continuous growth of the number of women of childbearing age, the group of pregnant women has become an important group that cannot be ignored in urban public spaces. In urban spaces, the concept of barrier-free space is used to create an environment where vulnerable people, such as those with disabilities, the elderly, and children, can use and access physical spaces without difficulty [2]. However, current research on barrier-free facility design still mainly focuses on traditional vulnerable groups such as the elderly and the disabled, while there are relatively few studies specifically on pregnant women. Pregnant women, as a special physiological group, face many inconveniences and potential risks during their travel and rest. Compared with biomedical causes, less attention has been paid to the underlying determinants of adverse pregnancy and childbirth outcomes and how health systems could be configured to implement effective interventions and mitigate the adverse effects of social factors on maternal health [3]. Due to hormonal changes, body shape changes, and psychological fluctuations during pregnancy, pregnant women have higher demands for the support, safety, comfort, and privacy of seats. In foreign countries, developed countries have earlier included mother and baby-friendly facilities in urban design. For example, some cities in Japan have set up special rest pavilions for pregnant women, and Germany has set up high-back flexible chairs designed specifically for pregnant women in parks. However, the existing urban public facilities in China are mainly designed for general use and cannot fully meet the physical and psychological needs of pregnant women at different stages of pregnancy, especially in the design of seats in public landscape spaces. Therefore, conducting research on barrier-free design of public space seats for pregnant women not only helps to improve their experience in using public spaces but also has significant im-

portance for building a friendly city and achieving design equity.

This study aims to conduct multi-dimensional research and analysis to clarify the core needs of pregnant women in the use of public space seats. By integrating existing research results and systematically sorting out and analyzing relevant literature and cases, a set of systematic barrier-free design strategies will be proposed, and a targeted public space seat design model will be ultimately constructed. The research content mainly includes: summarizing the physiological, psychological, and behavioral characteristics of pregnant women at different stages of pregnancy; extracting the preferences and needs of pregnant women for seat structure, function, material, and emotion through user research and behavior observation; systematically analyzing the demand hierarchy and structural innovation path through the KANO model, FBS method, and TRIZ theory; and proposing a set of feasible public space seat design solutions for pregnant women.

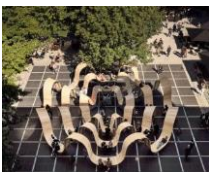
2. The Basic Concepts and Demographic Characteristics of Public Space Seating Design for Pregnant Women

2.1. The Definition and Functional Expansion of Seating in Public Spaces

Each public space possesses macro-, meso-(middle), and micro-environments -separate scales that interlink or overlap to form the whole [4]. Public space seating is one of the most fundamental and common human settlement facilities in urban outdoor environments, widely set up in parks, squares, walkways, transportation hubs and other public places. A survey of the existing public space seating such as Table 1. Its most basic function is to provide citizens with a spatial carrier for rest, waiting and conversation. At the same time, it also undertakes multiple functions such as guiding traffic flow, dividing areas, creating atmosphere and beautifying the environment. As an important component of urban space, public space seating not only has functional attributes but also participates in the overall spatial composition, enhancing the public nature and communicativeness of the urban environment. It can serve as both a rest point and a commemorative or artistic sculpture, enriching the visual layers and cultural connotations in urban space, adding more interesting urban elements and increasing the diversity of people's use of space. Through reasonable design and configuration, public space seating becomes an important medium for creating a free, equal and humanistic social atmosphere, reflecting the comprehensive significance of urban public facilities in terms of social value, cultural identity and group care.

Table 1. Classification analysis of public space seating.

Classification basis	Name	Pattern	Features
Material	Metal material chair		Strong weather resistance, stable structure, suitable for outdoor environments, and low maintenance costs.
	Wooden material seats		The texture is natural and the visual effect is warm, but it requires regular maintenance and care.
	Plastic material seats		Low cost, lightweight and durable, with a variety of colors, suitable for short-term use or temporary venues.
	Mixed-material seats		Combining the advantages of various materials, it has a flexible structure and can adapt to complex environmental demands.
	Single-seat chair		Independently designed, space-saving, and suitable for places with high privacy requirements (such as reading areas).
Style	Multi-person seat		The row-style structure promotes social interaction and is suitable for high-traffic areas such as squares and waiting areas.
	Back-to-back seats		Bidirectional design saves space and is commonly seen in circulation areas such as transportation hubs or atriums.
	Seats with armrests		It provides additional support and enhances safety, especially suitable for the elderly and those with mobility difficulties.
	Seating without armrests		The simplified structure facilitates quick seating and easy cleaning and maintenance.

Classification basis	Name	Pattern	Features
Design style	Tradition-al type seat		Make extensive use of natural materials (wood/stone), adopt symmetrical designs, integrate with natural landscapes, and emphasize a sense of history.
	Modern-style seats		Made mostly of metal or plastic, with a simple geometric shape, it is suitable for modern spaces.
	Creative-style seats		Artistic shaping (abstract/interactive), combining functionality and fun.

With the continuous deepening of the "people-oriented" concept, the design of public space seating has gradually expanded from meeting the general rest function to being friendly to diverse groups and providing emotional care. Against the backdrop of policies such as barrier-free design, healthy cities, and mother-and-baby-friendly spaces, how to meet the needs of special groups including the elderly, children, and pregnant women has become an important issue in the upgrading of contemporary urban public facilities. Among them, the design of public space seating for pregnant women, which combines physiological support and psychological comfort, has become an important part of the construction of refined and humanized urban facilities.

2.2. Analysis of the Characteristics of Pregnant Women Group

2.2.1. Analysis of Physiological Characteristics of Pregnant Women

Pregnancy is a physiological process accompanied by systemic changes throughout the body. During the entire pregnancy, a pregnant woman will experience a series of changes such as body shape, center of gravity, muscle tension, and internal organ load. These changes directly affect her daily behavioral habits, especially in public spaces, such as sitting, standing up, moving, and standing. Therefore, higher requirements are placed on the human-machine adaptability of public facilities [5].

1) Stages of pregnancy and physiological changes. Preg-

nancy is usually divided into the following three stages, each of which is accompanied by different physiological change characteristics, such as Table 2.

2) Changes in the skeleton and center of gravity. As the fetus grows, the pregnant woman's abdomen protrudes significantly. Changes in hormone levels during pregnancy can cause the sacroiliac ligaments to relax, resulting in a forward shift of the body's center of gravity, lumbar lordosis, and pelvic anteversion, which places greater stress on the sacroiliac ligaments that are trying to resist pelvic rotation. To maintain balance, pregnant women often adopt a stance with legs apart and the upper body leaning backward when standing or walking, which exacerbates lumbar lordosis and keeps the lower back muscles in a state of continuous tension. Coupled with the increasing weight of the woman herself and the fetus, this increases the pull on the spine and muscles of the back, leading to lower back pain in the later stages of pregnancy. The body of the pregnant woman automatically adjusts her standing and sitting postures such as Figure 1: the lumbar lordosis is enhanced. The spine undergoes a physiological "arched stretch" after the center of gravity shifts forward such as Figure 2, which can easily cause lower back pain; pelvic tilt. The pelvis slightly tilts backward to support the abdomen, causing the center of gravity in the sitting position to shift backward, requiring back support; increased burden on the hip and knee joints. When getting up in the middle and later stages of pregnancy, more force is exerted on the knees, increasing joint wear and fatigue [6]. The reduction in hip mobility-especially in the sagittal plane-and the increase in anterior pelvic tilt may contribute to muscu-

loskeletal discomfort and postural strain, ultimately affecting mobility and quality of life [7].

Table 2. Stage Characteristics of Physiological Changes During Gestational Period.

Pregnancy stage	Time range	Major physiological changes
Early stage	Weeks 1 - 12	Hormone levels fluctuate greatly, with common symptoms such as nausea, fatigue, and drowsiness. There is no obvious change in body shape.
Middle stage	Weeks 13 - 27	The abdomen starts to protrude, weight increases, the center of gravity gradually shifts forward, and one feels easily fatigued and needs more support.
Late stage	Weeks 28 - 40	The abdominal circumference is the largest, the lumbar lordosis is significant, the pelvis is compressed, there is a edema in the lower extremities, and the movement is slow and it is difficult to get up.



Figure 1. Changes in the abdomen and center of gravity during pregnancy in women (adapted from Casagrande et al.

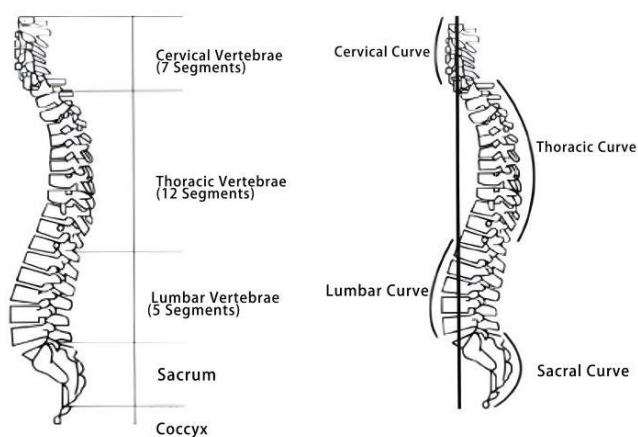


Figure 2. The normal structure and physiological curvature of the human spine.

Furthermore, during the middle and late stages of pregnancy, the increase in fetal and maternal weight compresses the intervertebral discs. Disc degeneration affected each of the pregnant women, with 61.3% low-grade, 22.4% moderate, and 16.3% high-grade degeneration, which increased

with age [8]. Not only intensifying the occurrence of lower back pain but also increasing the space requirements for actions such as standing up, turning around, and squatting. This places higher demands on the height, structure, armrests, and backrests of the seat, which are often difficult to meet by ordinary low seats in terms of providing adequate support for maintaining body balance.

3) Circulation and pressure on the lower limbs. Due to the growth needs of the embryo during pregnancy, the mother's blood volume increases and blood viscosity decreases to ensure smooth circulation. It is estimated that one in three women will develop CVD during pregnancy and that women exhibit an increased risk with the number of pregnancies [9]. Especially in the middle and late stages of pregnancy, the enlarged uterus compresses the pelvic veins, hindering blood return and easily causing problems such as lower limb edema and varicose veins. Prolonged sitting without adequate support in the pressure areas of the legs can exacerbate discomfort: feet tend to swell, especially after long periods of sitting or in hot weather; legs should be moderately elevated or spread apart to reduce venous pressure and improve circulation; upon standing up, some women may experience brief dizziness or instability and require reliable support structures to assist in completing the movement.

Therefore, when designing public space seating, considerations should be given to a slightly reclined seat surface, easy leg extension, and a seat depth that is neither too deep nor too low, while optimizing the user experience through material breathability and softness.

4) Physiological limitations during the process of standing up and sitting down. The use of seating by pregnant women can be broken down into pre-sitting behaviors such as "standing, shifting the center of gravity backward, and sitting down", relatively static sitting behaviors, and post-sitting behaviors such as "supporting, shifting the center of gravity

forward, standing up, and moving". Among these, the actions of standing up and sitting down are the most challenging aspects for pregnant women when using seats such as [Figure 3](#). In the later stages of pregnancy, the enlarged abdomen, increased burden on the lower limbs [\[10\]](#), and weakened core muscle strength make these actions require external support (such as armrests) to be completed: sitting down needs to be

done slowly and with a sense of balance maintained; standing up requires support from the upper limbs and a forward-leaning posture to shift the center of gravity; some pregnant women exhibit a movement chain of "one-sided hand support + leg push + slow standing up", which is slow, has delayed perception, and is unstable such as [Figure 4](#).

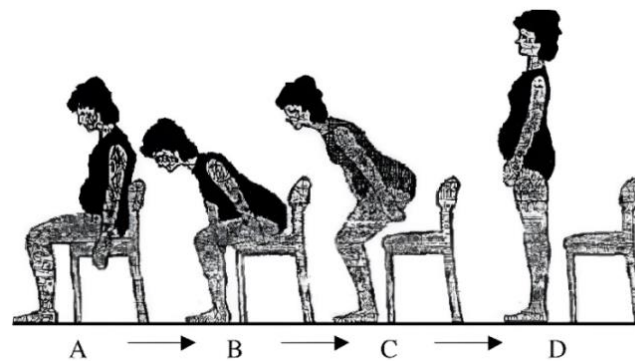


Figure 3. Sit-to-Stand Transition Process in Pregnant Women (Image source: <https://cn.bing.com/>).

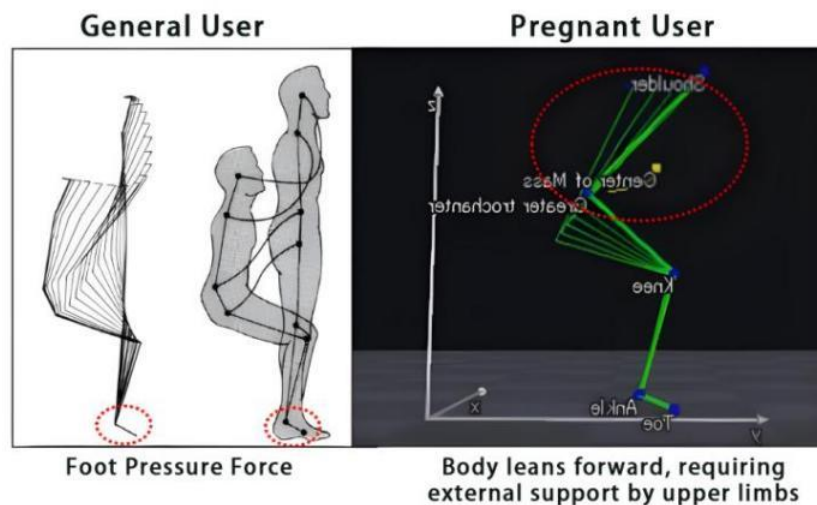


Figure 4. Comparison of Rising Maneuvers Between General Users and Pregnant Women.

2.2.2. Analysis of Behavioral Activities and Psychological Characteristics of Pregnant Women

During pregnancy, a woman's physical and mental states undergo significant changes, which directly affect her behavior in public spaces. As the pregnancy progresses, a woman's body shape changes, her center of gravity shifts forward, and she may experience problems such as lower back

pain, edema, and slower movement. Such as [Table 3](#), unlike the straight-line path that healthy people can take to reach their destination, pregnant women often exhibit behaviors such as "walking while observing and walking while resting" during their movement, making their paths intermittent and non-linear. Therefore, in public space environments, providing convenient, supportive, and buffering and guiding rest facilities becomes an important design task to serve the pregnant women group.

Table 3. Movement Path Characteristics of Different User Groups.

Healthy person	Children	Pregnant women, the elderly, and people carrying heavy loads	Wheelchair and Stroller users
			
One can reach the destination smoothly in a straight line.	Running, jumping, crawling and so on without a moment's rest.	Act while observing the surrounding situation and take a rest on the way.	It can be done relatively quickly when familiar with it, but it is more difficult when there are small turns or height differences.

Source: "Foreign Architectural Design Detail Drawings Collection 3 - Barrier-free Buildings"

From a psychological perspective, the stress caused by role transformation is the main source of pregnancy stress, during which they experience biological and psychological changes as well as changes in their status in the family and society [11]. These changes can lead to mental disorders of different types. The most common include increased levels of perceived stress and anxiety, and mood disorders [12-14]. Research shows that pregnant women with jobs tend to have more severe symptoms of prenatal depression compared to those without jobs. Pregnant women generally have sensitive, anxious, and easily fatigued emotional characteristics. Especially for those with jobs, they have more travel needs and a stronger demand for privacy and security during outdoor activities [15]. The lack of suitable seats will further increase their tension and reduce their willingness to go out, which is not conducive to their physical and mental health. In the design, the concept of emotionalization should be introduced to create a soft, comfortable, and inclusive environment to enhance their psychological safety and sense of belonging.

3. Characteristics of Traditional Public Space Seating and Barrier-free Design Principles for Pregnant Women's Seating

Public seating design is a new type of environmental product design that integrates industrial product design and environmental design, emerging along with the development of cities. In the 20th-century urban infrastructure construction, public seats were mostly set up following the principle of

"simplicity and universality", widely deployed in parks, squares, streets and other spaces. They were mainly targeted at healthy adults, with durability, neatness and aesthetics as the top priorities in design. With the increasing emphasis on barrier-free design in society, research on the usage needs and behavioral characteristics of specific groups (such as pregnant women, the elderly, children, etc.) has gradually deepened. Especially for pregnant women, they experience complex changes in body shape, behavior and psychology during pregnancy, and traditional public seats have exposed many problems in terms of adaptability. Based on the concept of barrier-free environment construction, the optimization of seats for pregnant women should be carried out from the following three aspects:

1) Combining the physical changes and support needs during pregnancy. In the middle and late stages of pregnancy, factors such as significant increase in abdominal circumference, forward shift of the center of gravity, lordosis of the spine, and swelling of the lower limbs cause pregnant women to move slowly, have difficulty sitting and standing, and have decreased balance ability. These physiological characteristics directly affect their ability to complete basic actions such as "sitting down - standing up" in public environments, and may even lead to secondary risks such as falls and muscle strains. Such as Table 4, traditional low, armless, and hard seats lack necessary auxiliary functions and may even induce fall risks. Therefore, seats should have a scientific height, stable armrest support, and a reclining backrest structure, and a moderately soft and hard seat surface to reduce the pressure on the lumbar spine and pelvis, enhancing the sense of safety and stability of the sitting posture.

Table 4. Movement Path Characteristics of Different User Groups.

Problems	Defects arise
The seat height is too low.	It's hard to get up when you sink too deep.

Problems	Defects arise
Lack of effective grabsping points.	There is no leverage available.
The material of the seat surface is too hard and has insufficient friction.	Sliding risk or local tenderness.
The backrest has a small tilt angle.	It cannot provide effective support for the lumbar vertebrae and is prone to aggravating fatigue.

2) Enhance spatial privacy and emotional relaxation functions. Pregnant women often experience mood swings during pregnancy due to physical discomfort, hormonal changes, and other factors. They are particularly sensitive to the sense of security, privacy, and psychological buffering capacity of the external environment. They tend to choose seats against the wall, in corners, or with partitions to obtain a certain emotional protection barrier. Traditional space seat designs are often in a rigid and unchanging form and are used everywhere without considering the spatial behavior of users, making it difficult to reflect the regional image of different locations. They often take shape and scale as the only variable features and actual measurements of design, focusing only on the surface contour modeling of objects. Such as Table 5, different geometric forms of seats have specific psychological implications in emotional expression. The traditional public seat arrangement is relatively open and symmetrical, lacking flexible transitions and psychological inclusiveness, which can easily cause anxiety or social pressure [16]. In terms of modeling language, simple seat forms are more likely to bring a sense of stability and trust to pregnant women. For example, smooth and flowing lines, natural and continuous boundary designs can convey a gentle and harmonious emotional atmosphere visually, reducing the anxiety during pregnancy. The use of rounded corners, curved connections, and horizontal line composition in seat details can further enhance the overall sense of security and visual pleasure [17]. Therefore, in the design of pregnant women-friendly public seats, visual stability, structural inclusiveness, and emotional relaxation functions should be comprehensively considered [18]. Through the gentle expression of design language, a reassuring and comfortable rest experience can be created for pregnant women [19].

Table 5. Emotional Expression of Seat Shapes.

Type	Emotional expression
Long bench	openness, order, efficiency, alienation, transience

Type	Emotional expression
Round seats	sense of security, equality, inclusiveness, cohesion, group pressure
Wavy shaped seats	exploration, fluidity, relaxed atmosphere, instability

3) Adapt to dynamic postures and multi-scenario usage. Pregnant women have diverse rest needs in different scenarios, including brief sitting, accompanying rest, waiting for pick-up, and temporary breastfeeding. Their usage rhythm and postures are not uniform. Traditional seats only offer static sitting support [20], with rigid structures and no consideration for "behavioral continuity". To enhance the comfort and spatial continuity for pregnant women, more flexible modular designs should be introduced, such as adjustable backrests or tilting structures to accommodate different posture transitions like "sitting upright - leaning back - lying on the side"; combined or segmented seat designs to support multi-functional interactions such as accompanying, holding infants, and temporarily placing items. These are all effective ways to improve adaptability [21]. Through structural expansion and functional linkage, the public space seats for pregnant women can transform from single-point rest nodes to composite spatial components with supportiveness, inclusiveness, and extensibility, meeting the needs of comfortable transitions and body relaxation in various scenarios.

4. User Research and Data Analysis

To accurately understand the real demands and behavioral characteristics of pregnant women when using seats in public spaces, this paper designed and distributed the "Questionnaire on the Use of Seats in Public Spaces by Pregnant Women". A total of 50 valid samples were collected through an online and offline combination approach, covering pregnant women of different ages, pregnancy stages, physical conditions and travel frequencies such as Table 6.

Table 6. Composition of the Study Sample (Pregnant Women in Public Spaces) (N=50).

Variable	Proportion (N=50)
Age group	25 - 30 years old (44%), 31 - 35 years old (34%), 18-24 years old (16%), over 36 years old (6%)
Pregnancy stage	Second trimester (48%), Third trimester (32%), First trimester (14%), Non - pregnant women companions (6%)
Body distribution	155 - 165 cm (56%), >165 cm (26%), <155 cm (18%)
Common physical conditions	Low back pain (66%), Lower limb edema (48%), Difficulty getting up (42%)
Whether it is the first pregnancy	Yes (62%), No (38%)

The survey results show that the respondents are mainly aged 25 - 35, accounting for 78%. Pregnant women in the second and third trimesters account for 80%. Among them, 66% have obvious low back pain, 48% have lower limb edema, and 42% report difficulty getting up. In terms of behavior, more than 60% of pregnant women travel more than 3 times a week. 52% of pregnant women in the second and third trimesters use public seats at least once a day. The main places of use are concentrated in daily travel routes such as park green spaces, community roads, and bus stops. Users

generally report problems such as the current seats being too low, having no armrests, insufficient backrest design, lack of shelter and psychological security, and hard materials, which cause both physical discomfort and emotional anxiety.

In terms of functional expectations, user feedback focuses on three levels: physiological support, privacy protection, and emotional relaxation. Combining the frequently appearing keywords and the statistical results of the multiple-choice rate, the core functional requirements of pregnant women for public space seats are summarized such as Table 7.

Table 7. Functional Needs of Public Space Seating for Pregnant Women: Support Rates and User Comments.

Seat function items	Support rate (N=50)	Keywords in user feedback (sample)
Armrest assistance+comfortable backrest support	82%	"It's okay when sitting down, but I have to grab something when standing up."
Provide sunshade and rain protection or arrange against the wall to create a sense of safety	64%	"It would be better to have trees and walls around, only then I can feel at ease."
Soft seat cushion, breathable and wear-resistant material	58%	"The wood is too hard, it's not warm in winter and too hot in summer."
Space for temporary belongings	46%	"I would love to have a place to put my bag when waiting for the bus."
Big enough space for sitting or small handheld	44%	"It could be better if it could hold a baby stroller."
Nighttime security: prompt, loud alert lighting or emotional promoted designs	32%	"It would be better if the lighting is softer, otherwise I'm afraid of the dark at night and I won't be scared at night either."

Thus, it can be seen that the needs of pregnant women for using seats have obvious hierarchical characteristics: First, the basic physiological adaptation needs represented by assistance in getting up and backrest support are the most direct demands for safety and functionality. Second, the emotional and psychological soothing needs related to the occlu-

siveness and flexibility of materials reflect a high dependence on a sense of privacy and environmental control. Third, the scenario adaptation needs that are linked to life behaviors such as breastfeeding extension and temporary placement of items demonstrate higher expectations for the systematic and multifunctional nature of seats.

The comprehensive survey results show that the behavior of pregnant women using seats in public spaces is not only restricted by the physical burden brought about by pregnancy but also deeply influenced by psychological emotions and spatial order. Their needs reflect a comprehensive feature of "safety - comfort - emotion - function" integration. This provides a clear user - perspective basis and quantitative support for the barrier - free design strategies and product modeling in the next chapter.

5. Analysis of Design Requirement Refinement and Theoretical Model Application

Based on the results of the user research in Chapter 3, the main problems faced by pregnant women during the use of public space seats are concentrated in aspects such as "difficulty in getting up, lack of support, lack of privacy, uncomfortable materials, and lack of behavioral adaptability". These problems reflect a highly coupled relationship among function, behavior, and structure, showing obvious physiological adaptability, emotional perceptibility, and scenario linkage. The FBS model has certain limitations in deeply exploring the internal relationship between user needs and product functions and how to meet these needs in the design process. The TRIZ theory accurately answers the core question of "how to do" in the design process, improving the efficiency and quality of product design. In view of this, this chapter is based on the FBS model, transforms user needs into specific design logics, and further combines the TRIZ theory to analyze and provide innovative inspiration for the key contradictions in the design.

5.1. User Demand Hierarchy Sorting

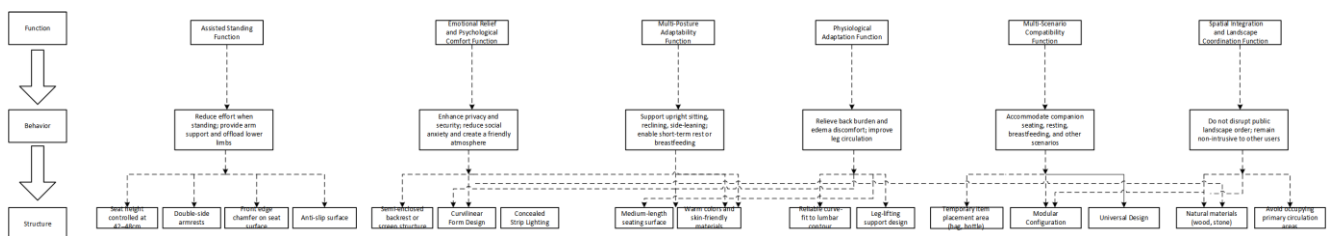


Figure 5. Function-Behavior-Structure Derivation.

The mapping results of the above requirements are further visualized such as Figure 4. This figure starts from the typical usage needs of pregnant women in public space seating and, through the three-level mapping relationship of "function-behavior-structure", gradually derives implementable

Based on the research and data analysis results in Chapter Three, pregnant women's use of public space seating shows a clear multi-level demand structure, which includes not only basic support and operational convenience at the physiological level, but also psychological comfort at the emotional level and multi-scenario adaptability at the behavioral level. This article categorizes these demands into the following three types:

First, physiological support needs: addressing basic physiological issues such as difficulty in getting up, back and waist fatigue, and lower limb discomfort, such as reasonable seat height, armrest design, backrest support, and breathable materials, etc.

Second, emotional and privacy needs: responding to pregnant women's demands for a sense of security and environmental control, such as shielding, wall/greenery layout, and emotional cues from color and shape.

Third, behavioral diversity needs: supporting posture changes and functional expansion in various usage scenarios such as accompanying, breastfeeding, waiting for medical treatment, and resting, such as adjustable seat surfaces, storage structures, and modular space.

5.2. Function-Behavior-Structure Mapping Analysis (FBS Model)

To transform user requirements into operational design logic, this paper adopts the FBS method for modeling. The design steps of the FBS model are shown in Table 8. The FBS model transforms the design problem into functional decomposition and function-to-structure mapping, and expresses the design information through three layers, i.e., function, behavior, and structure [22].

design elements and structural forms, achieving the transformation of users' emotional needs into product design logic.

This figure takes the six major functional requirements as the top-level logic of the functional layer, namely: getting up

assistance, mood relief, posture adaptation, physiological adaptation, multi-scenario compatibility, and space integration. Each function corresponds to a set of key behavioral requirements (such as reducing the resistance of getting up, enhancing privacy, supporting multiple postures, etc.), forming the behavioral layer; the behavioral layer is further mapped down to the structural layer, deriving a set of clear design construction items (such as increased seat height, double-sided armrests, modular layout, soft curved surface materials, etc.).

1) Function (F) - Behavior (B) Mapping: Oriented by the users' expected goals, identify the typical interaction behaviors presented by pregnant women when using the seat, such as sitting and standing, leaning back, turning sideways, being alone, breastfeeding, and placing items, etc. These behaviors constitute the core operation paths that the product should

support.

2) Behavior (B) - Structure (S) Mapping: Transform behavioral requirements into response mechanisms for the structure, providing clear support at the structural level through design means, such as raising the backrest to extend the stable support point for leaning back, using flexible seat cushions to respond to the comfort needs of long-term sitting, and adjustable sunshade structures to reflect users' adaptability to changes in the external environment.

This model, through step-by-step mapping and refinement of structural elements, constructs a clear, form-specific, and demand-oriented basic framework for the design of public space seating for pregnant women, effectively guiding the design transition from "emotional layer needs" to "rational construction logic", and providing a stable basis for structural definition and later innovation.

5.3. Innovative Design Path - Contradiction Analysis and Resolution Strategies Based on TRIZ

Table 8. Function-Behavior-Structure (FBS) Model.

Number	Current conflict issues	The Source and Manifestation
1	The contradiction between meeting the barrier-free needs of different groups of people (including all tall and short individuals, visually impaired and normal individuals)	The technical diversity requirements in FBS: "barrier-free design of equipment"; feedback from the research indicates the need to "adjust the height and width of the group of people".
2	The contradiction between structural stability and comfort: The overall structure needs to be stable, but armrests and backrest affect the experience.	The "physiological adaptation" of FBS in different environments: "the use of the actual material environment".
3	The conflict between multi-functional integration and simple appearance: rich in function (such as lighting, alerts, etc.) but prone to looking cluttered.	The "multi-scenario function" of FBS is in opposition to "spatial coordination".

Table 9. TRIZ Problem Transformation and Selection of Design Principles.

Number	Contradictory Parameters (TRIZ)	Recommended Invention Principles	Inspiring design strategies
1	Operability (No. 33) vs. Spatial Efficiency (No. 2)	NO. 4 Asymmetry NO. 3 Local Mass NO. 24 Mediator	The seat shape height and curve changes adapt to different heights. The armrests are embedded with Braille labels to enhance the sense of touch and recognition, while also increasing the friction for grasping.
2	Strength (No. 14) vs. Comfort (No. 33)	NO. 17 Add Dimensions NO. 14 Surface Curving NO. 15 Dynamics	The product is made of weather-resistant materials such as wood and metal. It features a curved surface design, an arc-shaped backrest with a curvature that fits the back, and a beveled seat surface (20mm), which reduces the feeling of pressure.

Number	Contradictory Parameters (TRIZ)	Recommended Invention Principles	Inspiring design strategies
3	Versatility (No. 35) vs. Appearance Attractiveness (No. 31)	NO. 6 Multi-functional NO. 10 Pre-action	Functional modules (such as lighting and alert) are embedded in the back of the armrest and backrest, maintaining a clean appearance and enhancing user convenience.

Developed by Genrich Altshuller [10], TRIZ provides a structured method for identifying and solving technical problems using patterns of invention found in the patent literature [23]. Based on the FBS model and user research, multiple typical conflict issues were exposed in the design of public space seats for pregnant women such as Table 7, including the dual demands for support and comfort, the balance between functional integration and visual space, and the conflict between privacy and accessibility. These problems not only manifest as contradictions at the user behavior level but also reflect systemic issues in the structural design. To address these conflicts, this paper introduces the engineering parameter comparison and inventive principles of TRIZ theory, combined with the design concept of barrier-free access and the requirements of outdoor scenarios such as Table 8, to integrate multiple independent systems and functions in an efficient and coordinated manner, achieving the maximization of overall product performance and the optimization of user experience.

Combining TRIZ inventive principles with the concept of barrier-free design, the innovative design of pregnant women's seats can be developed in the following directions:

1) Balancing privacy and openness: By using partially perforated screens, adjustable green plant enclosures, or sliding screens, a semi-private space can be created while ensuring barrier-free passage for wheelchairs and baby strollers.

2) Integrating support and comfort: Selecting hard materials suitable for outdoor use (such as wood, stone, or metal) to construct the seat structure, and combining a backrest curve that conforms to the curvature of the human spine, along with adding chamfers (about 20mm) to the seat surface to reduce edge pressure. Additionally, using soft and warm color tones (such as wood color or beige) in the material colors can provide psychological comfort.

3) Integrating functions and maintaining visual tidiness: Incorporating auxiliary functional modules (such as lighting, alerts, and charging) with hidden embedded designs, placed on the back of the armrests or backrests, to avoid affecting the overall appearance and the harmony of the public space.

In addition, principles such as the dynamicity principle (such as adjustable backrests and sliding screens), the principle of local quality (such as thickening key areas), and the

principle of increasing dimensions (using spatial layering design) can be applied to enhance the adaptability and innovation of the design.

6. The Application of TRIZ Theory in the Design Practice of Public Space Seating for Pregnant Women

Based on user demand research and FBS model analysis, there are multi-dimensional conflicts in the functional design, structural configuration, behavioral adaptation and psychological perception of public space seats for pregnant women. To solve these contradictory problems, this paper introduces the TRIZ theory, converts the core technical contradictions into innovative design paths, and systematically proposes optimization solutions from the perspectives of functional safety, structural stability, operational convenience and environmental integration, as follows:

6.1. Structurally, Ensure Safety, Stability and a Comfortable Experience

Combining the "standing assistance" function requirements in the FBS model with TRIZ theory, TRIZ principles 17 (increasing dimension), 14 (curved surface), 4 (asymmetry), and 3 (local quality) were adopted. The curved backrest design was optimized based on the physical characteristics of pregnant women. The seat angle was set at a slight 112° tilt (such as Figure), and the front edge of the seat was beveled (about 20mm) to reduce local pressure, alleviating the back pressure caused by prolonged sitting and enhancing comfort. Considering that the listed values should be increased by a certain margin when used in design to accommodate different clothing thicknesses and shoe heights across various regions in the country, the armrest design combined height adaptability with an asymmetrical shape to meet the support needs of pregnant women of different heights. The design utilized weather-resistant metal and wood materials to ensure safety and durability in long-term outdoor public use. The modular splicing structure facilitated maintenance and scene adaptation, embodying the integration of structural stability and adaptability, and optimizing the conflict between strength and comfort.

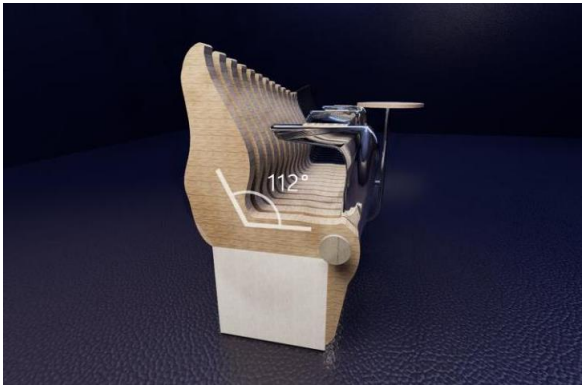


Figure 6. Curved backrest design.



Figure 8. Side hook design.

6.2. Functionally, It Reflects Humanistic Care for Pregnant Women and Special Groups



Figure 7. Small table bar design.



Figure 9. Barrier free design of handrail.

6.3. The Appearance Integrates the Beauty of Modern Environment and Scenes

To meet the diverse needs of pregnant women with different heights and visually impaired users, the seat integrates multiple functional modules based on TRIZ principles 6 "Multifunctionality" and 10 "Pre-action", including a small coffee table such as [Figure 7](#), embedded lighting, side hook design such as [Figure 8](#), USB ports and a voice prompt system, etc. These are designed with a hidden approach and sensor activation to ensure ease of operation and visual simplicity. The armrests are embedded with Braille labels and anti-slip wood textures such as [Figure 9](#), providing tactile cues and grip friction for visually impaired pregnant women. Additionally, a vibration reminder device is integrated, which triggers to prompt users to stand up, preventing the adverse effects of prolonged sitting on health. This demonstrates the design's humanized care and health management focus on the pregnant population.

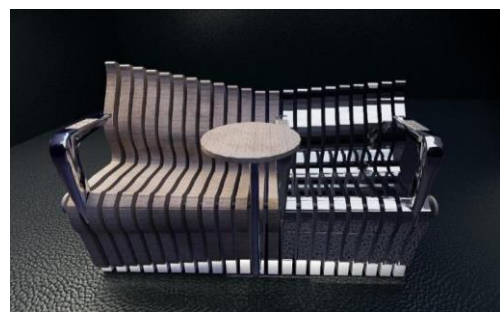


Figure 10. Appearance of seats in pregnant women's public space.

In terms of the integration of appearance and scene, the design applies TRIZ principle 24 "Intermediary" and principle 15 "Dynamicity". The seat shape is inspired by butterfly wings and combines the curves of pregnant women during pregnancy to create a warm and soft atmosphere. The curved shapes of the armrests and backrests are guided by dynamic lines to enhance visual guidance and psychological security.

The modular small coffee table and guiding light strip design solve the conflict between rich functionality and visual unity through flexible assembly and embedded layout, making the seat meet the diverse usage needs of pregnant women while conforming to the aesthetic requirements of public spaces such as Figure 10.

7. Conclusions

This paper takes the design of public space seats for pregnant women as the research object. By integrating the concept of barrier-free design, user research results and FBS theory analysis, it deeply analyzes the multi-level needs and key usage problems of pregnant women in rest spaces. Through the transformation of technical contradictions in function, structure and behavior based on TRIZ theory, an innovative design practice of barrier-free public space seats from the perspective of pregnant women is proposed. The design not only achieves systematic optimization in aspects such as functional safety, structural stability, barrier-free adaptation and psychological comfort, but also enhances the overall experience and sense of belonging of pregnant women and visually impaired people in public spaces through the integration of multi-functional modules and flexible shape design.

Abbreviations

FBS	Function-Behavior-Structure Model
TRIZ	Theory of Inventive Problem Solving
USB	Universal Serial Bus

Conflicts of Interest

The authors declare no conflicts of interest.

Appendix

Questionnaire on the Use of Public Space (Outdoor) Seating by Pregnant Women

Dear Madam: Hello! This questionnaire aims to investigate the real experiences, needs and feelings of pregnant women when using outdoor public seating, to understand the influence of different pregnancy stages, body characteristics and psychological states on the use of seating, and to provide a basis for the optimization design of barrier-free public facilities. All survey results will only be used for academic research, and the information will be strictly confidential. Thank you for your participation!

I. Basic Information (Multiple choices are allowed)

1. Your age range is:

☐ 18-24 years old ☐ 25-30 years old ☐ 31-35 years old ☐ 36

years old and above

2. Your current pregnancy stage is:

☐ Early pregnancy (1-13 weeks) ☐ Mid-pregnancy (14-27 weeks)

☐ Late pregnancy (28 weeks and above) ☐ Non-pregnant (accompanying person/related person)

3. Your height/weight range is:

Height: ☐ <155cm ☐ 155-165cm ☐ >165cm

Current weight: ☐ <60kg ☐ 60-75kg ☐ >75kg

4. Do you have any of the following physical conditions (multiple choices are allowed):

☐ Back pain ☐ Edema in lower extremities ☐ Mobility difficulties ☐ Shortness of breath ☐ Difficulty getting up ☐ No obvious discomfort

5. Are you in your first pregnancy currently?

☐ Yes ☐ No (Have given birth to one or more children)

II. Outdoor Public Seating Usage Experience

1. How many times do you go out on average per week (excluding indoor activities)?

☐ More than once a day ☐ 3-6 times a week

☐ 1-2 times a week ☐ Rarely go out

2. How often do you use outdoor public seating on average per week?

☐ Almost never ☐ 1-2 times ☐ 3-5 times ☐ Every day

3. Which public places do you usually go to? (Multiple choices are allowed)

☐ Parks and green spaces ☐ Commercial streets ☐ Outside hospitals ☐ Bus stops

☐ Community roads ☐ Outside schools/daycare centers ☐ Others: _____

4. What problems do you think exist in current outdoor public seating? (Multiple choices are allowed)

☐ The seats are too low, making it difficult to get up

☐ No backrest or the backrest is too short

☐ Lack of armrests

☐ The seat cushion is too hard or not breathable

☐ The environment is too open with no shelter

☐ The space is too narrow to accommodate strollers

☐ The material is not suitable for summer/winter use

☐ No place to put personal belongings

☐ Others: _____

5. During the process of using the seating, do you often need to rely on external forces (such as holding the armrest or leaning against the wall) to get up or sit down?

☐ Yes, often need to

☐ Occasionally need to

☐ Do not need to

6. Among the public seating you have used, what features do you like the most? (Multiple choices are allowed)

☐ Backed by a wall or green hedges, providing strong privacy

☐ Appropriate armrest position

☐ Soft and comfortable seat material

- ☐ No numbness in the legs after sitting
- ☐ The backrest angle fits the body
- ☐ Has a sunshade design or is under the shade of trees
- ☐ Others: _____

III. Psychological and Emotional Feelings

1. When staying outdoors for a short time, what do you care about most in the surrounding environment?

- ☐ Sense of safety (avoiding falls, snatching, etc.)
- ☐ Sense of privacy (avoiding being stared at)
- ☐ Sanitary conditions (clean seating surface)
- ☐ Sense of companionship (having a family member accompany)

- ☐ Emotional relaxation (can be alone and relax)

2. What emotional support do you hope public seating can provide you? (Multiple choices are allowed)

- ☐ A sense of safety and reliability
- ☐ A sense of being cared for and attended to
- ☐ A comfortable environment that makes you feel at ease
- ☐ Friendly to babies (can breastfeed/rest)

☐ Has related prompts or interactive designs for mothers and babies IV. Expected Functions of Future Public Seating (Multiple Choices Available)

If public seating could be customized for pregnant women, which of the following functions would you like to see included?

- ☐ Adjustable seat height / Armrest assistance
- ☐ Comfortable backrest support / Lumbar support
- ☐ Soft cushion / Replaceable seat surface
- ☐ Sunshade / Windbreak design
- ☐ Extended semi-private space for breastfeeding
- ☐ Mobile phone charging / Light indication
- ☐ Reminders for prolonged sitting / Emotional comfort prompts

- ☐ Child / Infant area included

- ☐ Others: _____

V. Supplementary Suggestions

What other improvements or suggestions do you have for the experience of using public seating outdoors?

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