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Role of Polymer and Composite Materials in Enhancing Durability and Comfort of Urban Park Furniture for Senior Citizens

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Abstract

Parks in urban areas are crucial in facilitating physical activities, socialization, and or mental health to the elderly citizens. Nonetheless, the traditional materials in outdoor park furniture may suffer in the form of low durability, weathering, ergonomics and maintenance, among other aspects and restrict long term applications of such furniture by the elderly population. The research question examined in the proposed study is: How can polymer-based and composite materials improve the durability, comfort, and functional performance of the urban park furniture of the elderly citizens? The study determines the suitability of polymer and fiber-reinforced composite materials in park furniture elements (seating benches, armrests, back supports, and safety elements) that are crucial in this aspect. Resistance to moisture, ultraviolet exposure, corrosion, temperature stability on the surface, ease of maintenance, and ergonomic adaptability material characteristics are analyzed. Material performance aspects are combined with user-parameters to comfort, safety, and usability of senior citizens to determine the suitability of the out-of-door urban setting. The material performance in the real conditions of climatic and usage conditions is put in perspective by a case-based evaluation of community parks. According to the findings, polymer materials and composite materials are superior in terms of durability, surface comfort, weather resistance, and maintenance than the traditional materials including timber and mild steel. Also, composites made of polymers provide a wider range of design possibilities, which allow it to be richer in age-friendly elements, including curved seating, non-slipping surface, and supportive armrests. The paper concludes that the strategic use of polymer and composite materials in urban park furniture has the potential of enhancing the long-term performance, user comfort, and sustainability but help in achieving an aim of age-friendly design. The results are practical information to material scientists, urban designers and manufacturers that would like to create durable, and senior-friendly outdoor infrastructure.

Keywords: Polymer composites, urban park furniture, senior citizens, outdoor materials, sustainable materials

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INTRODUCTION

Ageing of the population has become a characteristic demographic trend of the twenty first century. [1] The percentage of older citizens has grown at high rates all over the world as a result of healthcare, life expectancy, and urban environment advancements.[2] This trend has created an increasing demand on the creation of age-friendly cities that facilitate mobility, social interactions, and safety, and well-being.[3,52] Urban parks are among other infrastructures in the community that are important in enhancing physical exercise, mental renewal, and socialization among the elderly.[4] Parks have outdoor seating and support features which play a significant role in determining the usability of the parks by the elderly users. [5] The duration and frequency of the visits to parks are directly influenced by the comfort, stability, accessibility and thermal performance of park furniture.[6] Nevertheless, traditional materials that are typically utilized in outdoor furniture like timber, cast iron and mild steel tend to have shortcomings when subjected to extended weather conditions.[7] Timber is vulnerable to the uptake of moisture, biological breakdown, and cracks on the surface, whereas the metallic structures are vulnerable to corrosion, excessive heating of the surface in the sun, and periodical repainting. Material-related problems can shorten the life of the service, raise maintenance expenses, and undermine user comfort and safety, especially in relation to older people who are more susceptible to temperature extremes and ergonomic failures of materials.[8] On the one hand, the recent advancements in polymer science and composite engineering have provided the promising options of the outdoor structural and semi-structural applications. Composite materials (polymer based such as high-density polyethylene (HDPE), polypropylene (PP), and glass fibre-reinforced polymer (GFRP)) exhibit improved resistance to moisture, ultraviolet (UV) radiation, and corrosion as well as chemical attack.[9] Besides environmental sustainability, the materials offer design flexibility, thus allowing them to form ergonomics shaped seating contours, integrated armrests, non-slip surfaces, and lightweight yet structurally sound factors.[10] These features are especially applicable when considering the issue of senior-friendly infrastructure where the material performance needs to be in tandem with the comfort, safety and long-term usage specifications.[11] Although, polymers and composite materials are increasingly being used in outdoor products, there has been a dearth of research done to specifically identify them as systematic in enhancing the functional functionality of urban park furniture products to suit the aging population. The majority of current research work concentrates on material durability or landscape design and ageing separately, without considering any material science aspect and user-oriented performance parameters.[12] The current paper fills this gap by conducting an assessment on the applicability of polymer and fibre-reinforced composite materials in urban parks furniture designs that would be oriented to older people. The study explores some of the performance qualities such as moisture and UV protective characteristics, corrosive resistance, thermal stability on the surface, structural stability, maintenance and serviceability, and ergonomics.[13] These material properties are further studied in connection with the user parameters in terms of seating comfort, safety and usability at the real outdoor conditions. Through the correlation of material performance and age-friendly design, the paper seeks to give a viable understanding to material scientists, urban designers and manufacturers as to the development of durable and accessible outdoor infrastructure.[14]

LITERATURE REVIEW

Ageing Population and Age-Friendly Urban Infrastructure

The world has been experiencing a rapid rise in the population of the ageing population and this has increased the pressure on the urban environment to be age friendly.[15] Global demographic estimations show that those who are 60 years and over have one of the highest population growths in the world.[16] The cityscapes need to consequently shift towards becoming not only functional systems but inclusive and supportive of health ecosystems as well.[17] Age-friendly design is not only an accessibility standard but also a comfort, safety, ergonomic support and psychological reassurance standard.[18] The parks within the urban communities are vital in assisting emotional, social as well as physical wellness of the elderly as per the Indian context.[19] Nonetheless, other park infrastructure like seating, pathways, and handrails have a strong impact on the usability of the park.

The study of the case studies conducted at NOIDA (450 respondents in 15 parks) showed that:

- More than 80 percent of the elderly people patronized parks on a daily basis.
- It was found that comfort and accessibility of seating were some of the top-rated landscape parameters.
- Provision of shade, anti-slip paths and handrails had a significant impact on perceived safety.
- Seats that were senior friendly i.e. every 30-50 meters were greatly desired.

Table 1. Association between landscape features and well-being dimensions (NOIDA Case Study, n = 450.

Landscape feature	Emotional	Mental	Social	Physical	WMSR Score
Comfortable Seating	High	Moderate	Moderate	High	4.32
Shaded Areas	Moderate	High	Moderate	High	4.18
Barrier-Free Walkways	Moderate	High	Moderate	Very High	4.41
Non-slip Surfaces	Moderate	High	Low	High	4.25

These results demonstrate that furniture in the park is not the simple functional element of the park but the factor of frequency of visits, emotional comfort, and stress relief.

Landscape Features and Senior Citizen Well-being

An increasing amount of interdisciplinary literature creates a robust correlation between exposure to green settings and multidimensional well-being in elderly groups.[20] Urban restorative landscapes and parks help in reducing stress, improving mood, socializing more, and engaging in more physical activities.[21] These are especially important results to senior citizens, who are more susceptible to social isolation, lack of mobility, and environmental discomfort. Evidence based on empirical studies of the NOIDA case-based study (n = 450 older citizens of 15 community parks) supports the correlation.[22]

The research determined four major dimensions of well-being that are affected by park infrastructure:

- Emotional well-being
- Mental well-being
- Social well-being
- Physical well-being

The quantitative analysis of the responses (Weighted Mean Score of Responses or WMSR) indicated statistically significant relationships between particular landscape characteristics and the reported outcomes of the well-being. The quantitative associations between key landscape features and well-being dimensions are summarized in Table 1

Emotional stability and perceived relaxation were very much related with comfortable seating systems. [23]The access to shaded spaces was associated with longer stays and improved thermal comfort.[24] The absence of barriers in walkways also added to enhanced mobility confidence, especially on users who have to use a walking stick or assisted movement.[25] Safe and non-slip surface covers were associated with lower levels of mental stress and improved sense of safety.[26] Although the structure of the landscape features including vegetation intensity, spatial zoning, and access provision planning has been discussed extensively in both literature on urban design and literature on public health, the material functionality of the park furnishings has not been fully studied.

Available literature mainly focuses on:

- Vegetation planning and biodiversity.
- Spatial organization and circulation.
- Universal standards of accessibility.

Nevertheless, little academic focus has been placed on material-specific parameters that have a direct impact on long term comfort, and long-term durability, such as:

- Surface thermal behavior to the sun.
- Durability of long-term structures in the outdoor climate.
- Maintenance load and performance of lifecycle.
- Ageing and weathering resistance of materials. Ergonomic flexibility due to material mouldability.

Table 2. Comparison of traditional and polymer-based materials in park furniture.

Parameter	Timber	Mild steel	HDPE	GFRP
Moisture Resistance	Low	Moderate	High	High
Corrosion Resistance	Moderate	Low	Very High	Very High
Surface Thermal Conductivity	Moderate	High	Low	Low
Maintenance Frequency	High	Moderate	Low	Low
Ergonomic Mouldability	Limited	Limited	High	Very High
Expected Service Life	5–8 yrs	8–12 yrs	15–20 yrs	20+ yrs

To the old, the temperature on the surface, the feel of touch, and the solidity are not technical features as such but factors that define usability and safety.[27] High thermal conductivity materials can cause both uncomfortable and unsafe seating conditions during extreme changes in weather.[28] On the same note, hygiene and structural integrity can be compromised by surface degradation and corrosion, and this will reduce the functional life of the public furniture.[29] The material science principles in combination with the age-friendly landscape design are important in this research gap.[30] To create sustainable and elderly-friendly city park structures, a multi-faceted strategy of considering not only mechanical behaviour but also user-friendly comfort criteria of polymer and composite materials is needed.

Limitations of Conventional Materials in Park Furniture

Timber, cast iron, and mild steel are all conventional materials that have been used in urban park furniture in past because of its availability, structural familiarity and cost-effectiveness.[31] Nevertheless, their durability, surface performance and long-term usability are greatly influenced by their long-term exposure to the environment in the outdoors, especially infrastructure designed to serve the aged population.[32]

Timber

Timber is also in the outdoor benches and seats mechanisms commonly being used both due to its beauty and the perceived comfort.[32] However, its exterior performance is limited by a number of material-related limitations. Timber has hygroscopic nature and therefore tends to absorb moisture, swell and lose dimensional stability due to changing humidity conditions.[33] Reoccurring wet-dry processes cause surface cracking and splintering, and add to the biological degradation process, such as fungal growth and insect infestation. Not only do these factors decrease the structural integrity in time, but also cause more maintenance because of periodic sealing, treatment, and replacement. The deterioration of the surface may be dangerous to the senior users especially in the form of splinter injuries and uneven seating surfaces.

Mild Steel and Cast Iron

Structural frames and armrests are usually made of metallic material, mild steel and cast iron. Although these materials have high load-bearing capacity, they are prone to corrosion in the presence of moisture and other pollutants in the atmosphere especially in moist and urban areas. Corrosion causes the thinning of the material, loss of structural stability and esthetic degradation.[34] Coatings and occasional repainting is hence needed which adds to the lifecycle costs. Moreover, metals are fairly good thermal conductors. When in the presence of the sun over a long period, metallic surfaces may get heated and cause discomfort or even burns. On the other hand, in more colder climates metal surfaces can get too cold making it not very comfortable to the user. Such thermal changes are particularly troublesome to older people who prove to be highly sensitive to thermal extremes.

Table 3. Observed material performance issues in NOIDA parks.

Observed issue	Timber	Mild steel	Impact on senior users
Surface Cracking	High	Low	Uneven seating, splinter risk
Corrosion	None	High	Structural instability, injury risk
Paint Peeling	Moderate	High	Reduced aesthetic & hygiene
Surface Overheating	Moderate	Very High	Thermal discomfort
Slipperiness (Monsoon)	High	Moderate	Fall risk

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Observational Findings from NOIDA Parks

The studies involving the field observations at 15 community parks in NOIDA (n = 450 respondents) also support the performance constraints of the traditional materials. Issues that were frequently recorded were:

- Checking and degradation of wooden benches on the surface.
- Painting exfoliation and corrosion on metal armrests.
- Lack of thermal comfort on the exposed seats to the sun. According to senior respondents, there was a lot of discomfort in the following:
- Uncontrolled heating on the open surfaces during summer seasons. Cold metallic in winter.
- Smoother grip in the monsoon seasons.

These shortages which are material in nature have a direct impact on usability, safety perception as well as frequency of visits to the park.[35] The performance issues of the conventional materials make it clear that there is the need to move towards better alternatives of material systems that offer better weatherproofing and thermal stability, less maintenance load, and better ergonomic flexibility.[36]These flaws in the traditional timber and metal structures provide a strong ground on why polymer and fibre-reinforced composite materials should be considered as an alternative solution in thematic design of park furniture in old age.

Polymer and Composite Materials in Outdoor Applications

New development in polymer engineering and composite technology offers potential alternatives to traditional materials to be used in outdoor urban infrastructure. When discussing the age friendly design of parks, material performance should not only fulfill building needs, but also serve thermal comforts, safety levels of surfaces, strength and maintenance capacity- parameters that are highly manifested in the case-based NOIDA results. This field research on 15 community parks in NOIDA (n = 450 seniors) indicated that there were common problems with the timber and metallic furniture such as surface degradation, corrosion, overheating when exposed to sunlight, and slippery floors in the rainy season. These performance shortcomings were directly correlated with discomfort among the users, decrease in length of stay and safety issues. The key material-related deficiencies observed in the field study are summarized in Table 3.

The empirical evidence, thus, confirms the need to have alternative materials that can be reliable during varying climatic conditions and also materials that can cater to ergonomic needs of the elderly individuals. The polymer-based materials (High-Density Polyethylene (HDPE), Polypropylene (PP), Polyvinyl Chloride (PVC) and fibre-reinforced composites (Glass Fibre-Reinforced Polymer (GFRP usefulness of such materials directly counter other systems used in practice through their material property characteristics. Other recent research papers have also highlighted use of bio-based composite materials manufactured using agricultural residues in creation of environmentally friendly engineering materials. These bio-composites take natural fibers and waste biomass to turn them into materials that are environmentally friendly, have superior mechanical properties and less environmental impact on usage, and allow the principles of the circular economy in designing materials.[37] The possibility of natural fiber-reinforced polymer composite being used as an alternative material to the traditional material has been examined in recent studies as a potential way to use sustainable materials. As an example, fibre reinforced natural rubber bio-composites of Sansevieria cylindrica have been shown to possess better mechanical characteristics like tensile strength, modulus, and hardness because of high fibre-matrix interfacial bonding. [38]These results demonstrate the potential of the natural fiber composites to deliver sustainable and long-lasting material solutions to engineering and structural applications. Lignocellulosic fibers like ramie which are natural are increasingly being used as a reinforcement in polymer composites due to their environmental friendliness and renewability. LS washing and other surface treatments have the capability to improve the physical and thermal characteristics of the ramie fibers, making them easier to use in composite production. [39] The literature behind Areca catechu fiber reinforced epoxy composites has documented enhanced mechanical properties (i.e., tensile and flexural strength) as a result of favorable fiber/matrix interaction and filler reinforcement thus demonstrating the potential of natural fibre composites to be used in structural and outdoor material applications.[40] The application of recycled industrial and wood-based waste as reinforcement fillers in thermoplastic composite has been investigated in recent studies. As an example, manhole cover flour, medium-density fibre-board (MDF) sawdust has been already recycled into polypropylene composites and it is observed that the material has been able to improve bending strength, modulus, and thermal stability and also retain low water absorption.[41]The benefits of hybrid fibre-reinforced polymer composites as described in recent studies are that the materials incorporate natural and synthetic fibres into a polymer matrix to improve the mechanical and thermal performance. The methods of hybridization may enhance considerably the characteristics of materials like strength to weight ratio, fracture toughness, and durability, which makes such materials to be applicable in engineering and structural work.[42]

Moisture and Corrosion Resistance: As compared to timber, polymer materials do not absorb moisture negligibly and also do not biodegrade. Equally, fibre-reinforced composites are naturally resistant to corrosion, so structural thinning and coating failure is not found in mild steel components in wet surroundings.[43] As there have been instances where several NOIDA parks showed signs of paint peeling and corrosion starting in metal armrests, the use of GFRP and polymer systems as corrosion-resistant materials has a great improvement in the lifetime of the material. A comparative assessment of resistance characteristics is presented in Table 4

These properties directly address the corrosion and surface degradation documented in NOIDA parks.

Thermal Performance and Surface Comfort

The case study has shown that thermal discomfort was one of the key issues as the respondents stated that it was overheating during summer and cold metallic pains during winter. Thermal conduction of metals is high hence quick absorption and transmission of heat. Polymers and composite materials, on the other hand, have comparatively low thermal values, which means that surface temperatures are moderated in direct sunshine. This feature is especially applicable to the elderly users as they are especially sensitive to temperature extremes and can be less tolerant to temperature discomfort. The safety and the perceived comfort of polymer-based seating systems are enhanced by both the minimization of cold-touch impacts and reduction of peak surface temperature. The relative thermal behavior of materials is illustrated in Figure 1.

Structural Stability and Ergonomic Adaptability

Fibre-reinforced composite especially GFRP have high strengths to weight ratio and dimensional stability within varying environmental conditions. Composite materials do not change structurally with time unlike timber which is subjected to swelling and shrinkage.[44] Notably, polymer composites can be used to confer moulded and shaped geometries, which are hard to accomplish in the customary materials. The case study of NOIDA established that the users wanted to strongly prefer:

- Curved back supports Only
- Armrests to help sitting and standing.
- Anti-slip seating textures
- Flattened edges to minimize level of injury.

Table 4. Comparative moisture and corrosion resistance of materials.

Material	Moisture absorption	Corrosion resistance	Suitability for humid climates
Timber	High	Moderate	Low
Mild Steel	Low	Low	Moderate
HDPE	Very Low	Very High	High
GFRP	Very Low	Very High	Very High

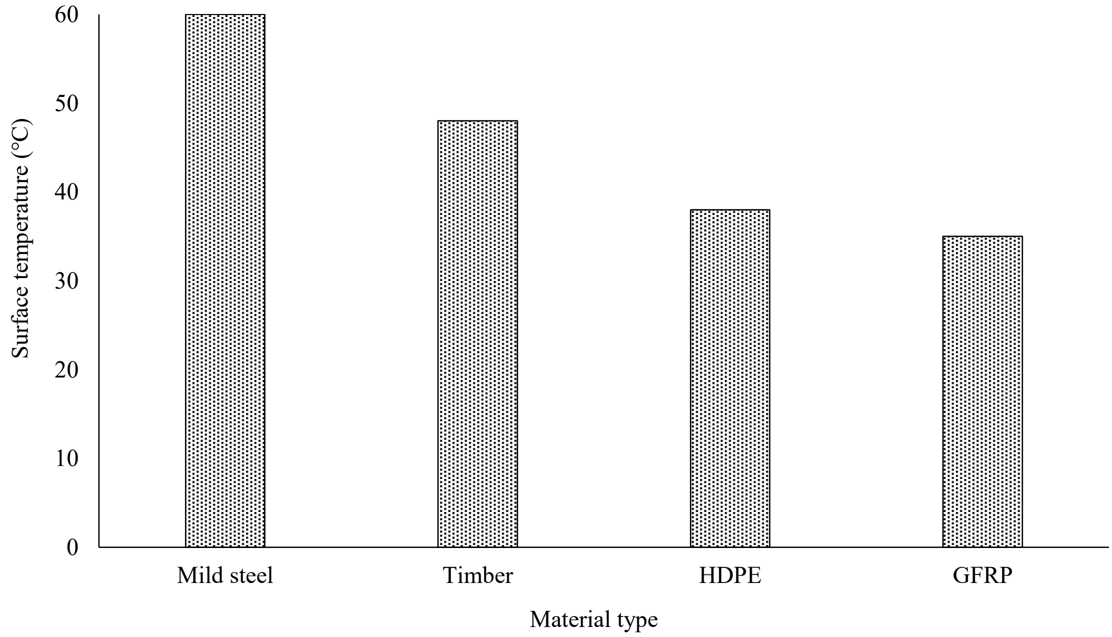

Figure 1. Comparative surface temperature behavior of conventional and polymer-based materials after 6 hours of solar exposure.

Composite and polymer materials enable the incorporation of these ergonomics aspects in one molded system without assembling many components. This integration promotes safety and continuity of the structure and minimizes mechanical joints which are likely to fail.

Maintenance and Lifecycle Efficiency

Field observations showed the presence of common problems in timber and mild steel furniture such as repainting, sealing and replacement of worn parts. Polymer composites are hardly maintained because they do not corrode, splinter or have to undergo periodic surface treatment. Their long lifespan (which is in most cases more than 15-20 years) helps in lowering the cost of lifecycle and maintenance activities in the public parks where the maintenance budget is rather smaller. Lifecycle comparison is presented in Figure 2.

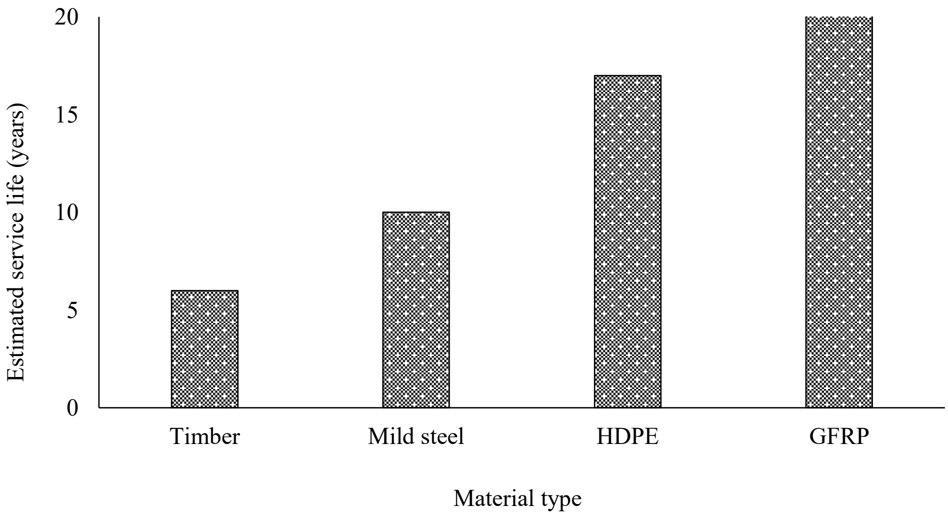

Figure 2. Estimated lifecycle performance comparison of conventional and polymer-based materials used in urban park furniture applications.

Sustainability Considerations

Recycled plastic composites have been used in many modern outdoor systems based on polymer materials, which helps to achieve material circularity and waste minimization.[45] Polymer composite when assessed in terms of lifecycle parameters, durability, frequency of maintenance, and replacement cycles, has a potential of offering reduced environmental impact in the long run, in comparison with the existing treated timber or coated metal systems.

Materials and Methodology

The research paper is a mixed-method based on both empirical field research and comparative material performance research. The research design was chosen in a way that it assesses the correlation of material properties and the comfort parameters of users in urban park furniture targeting elderly individuals.[46,53]

Study Area and Sample Selection

The quantitative study was done in fifteen (15) community parks situated in NOIDA, Uttar Pradesh, India. The chosen parks are neighborhood level open spaces or parks with heavy pedestrian use by senior citizens, and they have the traditional outdoor seating systems made mostly of timber planks on mild steel frames.[47] The selection criteria was set based on the factor (i) that they are frequently used by aged populations, (ii) that they have traditional material-based furniture systems, and (iii) they are exposed to different environmental conditions, such as full sun exposure and partial shading installations. NOIDA has a compound climatic regime with excessive seasonal difference. Summer temperatures often reach around 45 o C with winter temperatures dropping down to about 5 o C. Humidity is between 30 85, and the annual 800-900mm rainfall is received in the region.[48] This kind of climatic change exposes outdoor furniture materials to repetition of thermal cycling, ultraviolet radiation, moisture adaptation, and corrosion promoting environments. These are the environmental stresses, which play critical parameters in determining long-term durability, surface stability and lifecycle performance of outdoor materials. The sampled parks were of about 0.5 up to 2.5 hectares with 12 to 30 fixed seating units in each of the parks. The seating systems were dominant in the pedestrian circulation areas and activity space with minimal protective cover. The classification of exposure was created considering the direct solar radiation and duration and canopy cover. Seating units that were getting over five hours of direct sunshine per day were classified as sun-exposed and sun-shaded units that were under the tree canopy cover of over 50%. This classification allowed the correlation of the intensity of environmental exposure and material degradation observed. The sample size used in the study was 450 elderly individuals (aged 60 years and above). Purposive sampling was embraced in order to make sure that normal users of the park are included in the sample and those who are regular users of the seating systems. The selection of respondents was done to ensure that minimum four visits were made to the park per week. The sample size was deemed sufficient to conduct perception-based assessment and material performance assessment in the context of the study area. The field work was carried out during three months of field work which included peak summer and transitional climate. This time allowed thermal discomfort behavior to be observed, overheating behavior of the surface, corrosion onset, cracking of the timber and slip issues to be observed under different environmental stress conditions. Furniture condition assessment was conducted by systematic on-site observation along with the respondent feedbacks. Parameters of evaluation were; timber surface degradation (cracking, splintering, swelling), steel corrosion and failure of coating, reported thermal discomfort, and slip hazard in the presence of monsoon conditions. All the parameters were qualitatively rated and summed up to provide an overall rating of the condition using a performance scale with five points where 1 indicated poor condition with high deterioration and high risk, and 5 indicated excellent condition with low deterioration. The consolidated assessment of the selected parks is presented in Table 5.

Data Collection Methods

A structured empirical method combining the use of a survey based on perception and a validation method that relied on observation was applied in the data collection process.[49] The aim was to set up correlation between material performance characteristics and user comfort, safety perception and usability parameters in the case of the senior citizens.

Table 5. Selected parks and furniture condition assessment (NOIDA case study).

Park code	Exposure condition	Timber degradation level	Steel corrosion level	Thermal discomfort reports	Slip risk (monsoon)	Overall condition rating*
P1	Predominantly Sun-Exposed	High (Surface cracking, splintering)	Moderate	High	High	2
P2	Mixed Sun & Shade	Moderate	Moderate	Moderate	Moderate	3
P3	Sun-Exposed	High	High	Very High	Moderate	2
P4	Sun-Exposed	Moderate	High (Paint peeling observed)	High	Moderate	2
P5	Partially Shaded	Moderate	Moderate	Moderate	Low	3
P6	Sun-Exposed	High	High	Very High	High	2
P7	Mixed	Moderate	Moderate	High	Moderate	3
P8	Sun-Exposed	High	Moderate	High	High	2
P9	Sun-Exposed	Moderate	High	Very High	Moderate	2
P10	Partially Shaded	Moderate	Moderate	Moderate	Low	3
P11	Sun-Exposed	High	High	High	Moderate	2
P12	Mixed	Moderate	Moderate	Moderate	Moderate	3
P13	Sun-Exposed	High	High	Very High	High	1
P14	Partially Shaded	Moderate	Moderate	Moderate	Low	3
P15	Sun-Exposed	High	High	Very High	High	1

Overall Condition Rating: (1)= Poor (Significant degradation, safety concern): (2)= Below Average (Noticeable deterioration):, (3)= Moderate (Usable with maintenance need),(4) = Good5 (5)= Excellent
Source: Synthesized from field observations and respondent feedback documented in the NOIDA case study.

Table 6. Questionnaire parameters and measurement scale.

Parameter evaluated	Description of assessment	Measurement scale (1–5)	Material performance relevance
Seating Comfort	Perceived ergonomic support and backrest adequacy	1 = Very Poor, 5 = Excellent	Ergonomic adaptability
Surface Temperature Perception	Thermal comfort under sun exposure	1 = Extremely Uncomfortable, 5 = Comfortable	Thermal conductivity behaviour
Structural Stability	Perceived firmness and absence of wobbling	1 = Unstable, 5 = Very Stable	Structural integrity
Slip Resistance	Safety during wet conditions	1 = Highly Slippery, 5 = non-slip	Surface texture performance
Maintenance Condition	Visible wear, corrosion, cracking	1 = Poorly Maintained, 5 = Well Maintained	Durability & lifecycle
Duration of Stay	Average time spent in park seating area	Measured in minutes	Comfort sustainability
Parameter Evaluated	Description of Assessment	Measurement Scale (1–5)	Material Performance Relevance
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Slip Resistance	Safety during wet conditions	1 = Highly Slippery, 5 = non-slip	Surface texture performance
Maintenance Condition	Visible wear, corrosion, cracking	1 = Poorly Maintained, 5 = Well Maintained	Durability & lifecycle
Duration of Stay	Average time spent in park seating area	Measured in minutes	Comfort sustainability

Structured Questionnaire Survey: A questionnaire was designed in a structured format to measure the interaction of the user with the available park furniture systems made of timber and mild steel.[50] The tool was developed to record comfort parameters of materials and perceived performance weaknesses in actual outdoor conditions of exposure. The survey involved the measurement of seating comfort, temperature of the perceived surface, structural stability, slip-resistance, the maintenance condition, and duration of the stay in the park. The choice of these parameters was based on the fact that they directly determine the functional and ergonomic performance of outdoor furniture materials. The responses were collected through a five-point Likert scale with a response of 1 (Very Poor) to 5 (Excellent).[51] The responses obtained were analyzed by use of the weighted mean score of responses (WMSR) method in order to establish the relative importance of each parameter.

The evaluated parameters and measurement scale are presented in Table 6.

Weighted mean score of responses (WMSR): The WMSR was used to measure the relative importance of each of the parameters considered with respect to furniture performance. The procedure allows converting ordinal Likert-scale answers into a similar numerical index. The following expression was used to compute the WMSR:

The WMSR for each parameter was computed using the following expression:

$$WMSR = \frac{\sum_{i=1}^{k}(f_i \times w_i)}{N}$$

Where: f_i= frequency of responses corresponding to scale value $w_i w_i$= weight assigned to Likert scale value (1 to 5) N= total number of respondents

where $f_i$represents the frequency of responses corresponding to the Likert scale weight w_i, $k$denotes the number of response categories (five-point scale), and N represents the total number of respondents.

NPI=\$frac${$WMSR$} {5}

The five-point Likert scale was assigned weights ranging from 1 (Very Poor) to 5 (Excellent). The aggregated weighted score was divided by the total number of respondents to obtain the mean performance index for each evaluated parameter.

For illustration, the WMSR calculation for the parameter “Seating Comfort” is presented in Table 7.

$$WMSR = \frac{1640}{450} = 3.64$$

The value calculated of 3.64 represents high degree of perceived performance regarding the seating comfort. For interpretative consistency, WMSR values were classified into performance categories as shown in Table 8.

Table 7. Sample calculation of WMSR for seating comfort.

Likert scale (w_i)	Frequency (f_i)	$f_i \times w_i$
1	20	20
2	50	100
3	110	330
4	160	640
5	110	550
Total (N = 450)	—	1640

Table 8. Interpretation range of WMSR values.

WMSR Range	Performance interpretation
4.1 – 5.0	Very High
3.1 – 4.0	High
2.1 – 3.0	Moderate
1.1 – 2.0	Low
≤ 1.0	Very Low

To facilitate comparative material-performance assessment, a normalized performance index (NPI) was further derived:

$$NPI = \frac{WMSR}{5}$$

where 5 represents the maximum Likert scale value. The normalized index ranges between 0 and 1, enabling standardized comparison across evaluated parameters.

The WMSR analysis has been the analytical foundation of the priority of the seating comfort, thermal perception, stability, slip resistance, and maintenance condition and, thus, it has been possible to correlate the material-related shortcomings with the user comfort perception at the chosen parks.

RESULTS AND DISCUSSION

Condition Assessment of Conventional Materials

The observation conducted in fifteen parks demonstrated that the patterns of degradation of timber and mild steel furniture systems were similar. Parks under the dominant sun exposure were found to have more severity of timber cracking, splintering as well as dimensional instability. The steel parts exhibited corrosion forms, peeling of paint and corrosive surface erosion. Parks P13 and P15 had the lowest total rating of conditions (1), which is identical with high thermal discomfort and high levels of corrosion as shown in Table 5. The effect of the environmental stress on traditional materials was proven as sun-exposed installations demonstrated a more rapid process of the material ageing in comparison to half-shaded units. These results confirm that thermal cycling, ultraviolet exposure and ingress of moisture are the key factors that lower service behavior of timber and mild steel systems under composite climatic conditions.

WMSR-Based User Perception Analysis

The analysis of the Weighted Mean Score of Responses (WMSR) demonstrated that seating comfort, barrier free walkways, and non-slip surfaces did not take the last place in the ranking of the parameters that affect elderly well-being "Table 1". Perception of surface temperature has relatively lower scores of performances in the sun-exposed parks, which are consistent with complaints of overheating complaints during summer or cold metallic in the winter by the respondents.[50] Moderate performance ratings were also registered when it comes to slip resistance during monsoons, which demonstrates the constraints of traditional materials in terms of surface texture. The values of normalized performance index (NPI) showed that the factors that had significant effects on the overall perception of usability were thermal discomfort and maintenance condition.

Correlation Between Exposure Condition and Material Degradation

The correlations were determined based on a qualitative correlation between exposure classification and condition rating. Parks listed under the category of Sun-Exposed had:

- Increased rates of degradation of timber.
- Higher cases of steel corrosion.
- High reports on thermal discomfort.
- Lower general state ratings.

This relationship supports the significance of the thermal conductivity, waterproofing, and UV stability in the selection of outdoor materials in the long-term.

Comparative Performance of Polymer and Composite Materials

Table 2 and Table 4 show the comparative evaluation of HDPE and GFRP system in major parameters:

- Extremely low absorption of moisture.
- High corrosion resistance
- Less surface thermal conductivity.
- Extended service life (15–20+ years)
- Large ergonomic mouldability.

The low thermal conductivity of the polymer-based materials helps in reduced surface temperatures in the long run exposure to the sun, hence the elimination of thermal discomfort to a minimum. Also, composite mouldability allows the incorporation of a curved backrest, armrest, anti-slip surfaces and rounded safety edges into one structural system. These features directly deal with the shortcomings that were noticed in the traditional timber and mild steel structures in the NOIDA parks.

Lifecycle and Maintenance Implications

According to lifecycle comparison (Figure 2), systems based on polymers present much longer service life than traditional materials. Timber structures need to be regularly sealed and replaced whereas mild steel buildings need to be repainted and corroded regularly. On the contrary, polymer composites show low maintenance and structural stability in the face of environmental exposure. Increase in the number of maintenance cycles is part of the long-term economic and environmental sustainability.

Engineering Implications for Age-Friendly Design

Incorporation of polymer and fibre-reinforced composite materials contributes considerably to the functionality of furniture in urban parks, which improves thermal comfort, diminishes the risk of slipping, allows the structure to be more stable, offers a longer lifecycle performance, and ergonomically adaptable. Due to their low thermal conductivity, corrosion resistance and mouldability, these materials deal with major shortfalls that have been witnessed in the traditional timber and mild steel systems especially in changing outdoor climatic conditions. According to the material science viewpoint, the results reveal that mechanical durability is not a sufficient factor in the case of senior-centric infrastructure; the tactile comfort, surface thermal behavior, and safety features of the surface are also greater determinants of usability. The paper thus demonstrates a direct and quantifiable correlation between material choice and multidimensional well-being success, such as emotional comfort, perceived protection, confidence in mobility and prolonged use of parks among the elderly demographics.

CONCLUSION

In the current research, the impact of polymer and fibre-reinforced composite materials on the quality of durability, comfort, and functional performance of the city park furniture on the elderly population was assessed. In the empirical field research on fifteen community parks located in NOIDA (n = 450 respondents) massive performance shortcomings were found in traditional timber and mild steel systems and especially when subject to the composite climatic conditions. It was shown in the analysis that environmental stressors like thermal cycling, moisture ingress, corrosion, directly affect the material deterioration and have a direct correlation with perception of comfort and safety by the user. Comparative analysis revealed that the polymeric composites like HDPE and GFRP had a high resistance towards moisture, corrosion and exposure to ultraviolet in addition to being less thermally conductive and more ergonomically mouldable. These features allow the addition of age-friendly design and decrease maintenance load and life cycle costs. The results demonstrate that material choice is a significant element towards the realization of age-friendly urban infrastructure. Outdoor seating systems can be improved greatly in terms of durability and surface comfort, structural integrity and sustainability through strategic use of polymer and composite material. In the future, experimental laboratory testing of thermal conductivity, tensile strength, and fatigue resistance can be used to further measure the benefit of polymer composite systems in performance in simulated environmental conditions.

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