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Home and neighbourhood built environment latent class profiles and young children's developmental vulnerability

Findings from the Australian Early Development Census

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Research Summary

Why was the research done?

The early years of a child's life are crucial for their health and development, and the neighbourhood they grow up in can play an important role. However, we still don't know enough about how the physical features of neighbourhoods—like parks, public transport, and traffic—affect young children's development.

What were the key findings?

In this study, Australian Early Development Census (AEDC) data were linked with geospatial measures of the neighbourhood built environment for 5,033 children in Perth, Western Australia. We found five types of neighbourhoods, ranging from well-connected established areas to more rural ones.

Children living in neighbourhoods with good access to quality parks, early childhood education and care centres, and public transport were less likely to be developmentally vulnerable. In contrast, children living in areas with fewer destinations and more traffic were more likely to face developmental challenges.

What does this mean for policy and practice?

These findings provide direction for policy makers and parents to prioritise the design of neighbourhood built environments that better support early child development.

Citation

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We acknowledge the Traditional Custodians of the lands on which we work and live across Australia. We pay our respects to Elders past and present and recognise their continued connections to land, sea and community.

Home and Neighbourhood Built Environment Latent Class Profiles and Young Children's Developmental Vulnerability: Findings from the Australian Early Development Census

Abstract

Introduction

Children's developmental outcomes in their early years have lifelong consequences for later health and wellbeing. Despite persistent geographical inequities in early development, the specific role of the neighbourhood built environment remains underexplored. Understanding how different neighbourhood typologies influence early development can inform more equitable urban planning and policy for children.

Objectives

To identify typologies of neighbourhood built environments and assess their association with early childhood developmental vulnerability, and whether these associations differ by area-level disadvantage.

Methods

Australian Early Development Census (AEDC) data were linked with geospatial measures of the neighbourhood built environment for 5,066 children in Perth, Western Australia. Latent profile analysis identified neighbourhood built environment profiles based on features such as access to green space, movement network, and child-relevant destinations. Logistic regression models tested associations between built environment profiles and developmental vulnerability, stratified by area-level disadvantage.

Results

Overall, 21.8% of children were developmentally vulnerable on at least one AEDC domain. Five built environment profiles emerged: 'Average neighbourhood', 'Established neighbourhood', 'Low destinations and transport mix', 'Connected housing', and 'Disconnected semi-rural'. Children in the 'Established neighbourhood' profile had the lowest proportion of developmental vulnerability (18.3%), while those in the 'Disconnected semi-rural' profile had the highest proportion (25.8%). In more disadvantaged areas, associations between built environment profiles and developmental vulnerability were less consistent.

Conclusions

Neighbourhoods with better access to child-relevant destinations, attractive green spaces, and public transport were associated with lower developmental vulnerability. Conversely, neighbourhoods with a substandard movement network, less destination access, and higher traffic exposure were linked to worse early development outcomes. These findings provide direction for policy makers and parents to prioritise the design of neighbourhood built environments that better support early child development. Further studies should focus on unpacking the mechanisms through which individual and combined effects of features of the neighbourhood environment influence early development.

Introduction

Early childhood (0-8 years) marks an important phase when one's environment critically influences how the brain develops, translating to health and well-being outcomes across the life course [1]. Access to enriched environments early in life supports optimal childhood development. For example, young children who live with highly educated, high-income neighbours show better achievement at school [2]. In contrast, children who are exposed to challenging environments, such as poverty and frequent relocation, are at increased risk of developmental problems [3].

To map, monitor and evaluate the impact of policy and services on early childhood development, some countries have employed population-wide measures. For example, the Australian Early Development Census (AEDC) collects data from at least 96% of eligible children, providing a robust representation of the population [4]. Data from the AEDC are used to determine if children are 'developmentally on track', 'developmentally at risk' or 'developmentally vulnerable' across five domains: Physical health and wellbeing, Social competence, Emotional maturity, Language and cognitive skills (school-based), and Communication skills and general knowledge. The 2024 AEDC report indicates that 23.5% of Australian children are developmentally vulnerable in at least one developmental domain [4], highlighting the need for research to help develop effective interventions.

The socioecological framework [5] can be used to unpack how environmental factors potentially impact children's early development. This framework emphasises that a child develops through the interplay of multiple nested influences, from the individual and family, to the broader impact of the neighbourhood and society. The immediate surroundings of a child's home and neighbourhood built environment can play a crucial role in early development through shaping daily experiences, exposures, and access to essential services and resources [6]. The built environment consists of the design and construction of infrastructure created or modified by people, including features such as housing, street design, traffic, parks and other community spaces [7, 8]. Importantly, investigating the impact of built environments on early child development provides an opportunity for optimising these environments to help minimise early child developmental vulnerabilities [9].

An evolving body of research has highlighted the role of the built environment in influencing early child development [6]. For instance, access to green spaces (e.g., parks, home yards) has been associated with higher levels of physical activity and outdoor play [10], enhanced cognitive [11] and social-emotional development [12]. Similarly, access to child-relevant destinations and services, such as early childhood education and care centres, is important for supporting various early child development outcomes [9]. Easier access to public transport has also been associated with more favourable developmental outcomes [13]. Overall, the evidence to date suggests that the neighbourhood environment in which children live can attenuate or accentuate early childhood development.

Nevertheless, current research investigating the impact of the built environment on early childhood development is limited in its exploration of the underlying pathways. One potential barrier is that many built environment features are interdependent, interact, or are correlated through complex mechanisms. For example, high-density areas could have shorter distances to beneficial destinations, but increased traffic exposure [13]. Additionally, built environment features could have a combined, rather than standalone, effect. For example, green space (e.g., parks, nature), blue space (i.e., oceans, rivers and lakes), and home yards may all collectively and accumulatively influence early childhood development by promoting outdoor play [14]. A deeper understanding of how different built environment features interact and influence early child development is needed to disentangle the impacts of their combined effects.

Here, latent profile analysis offers an innovative method of identifying clusters of built environment features, revealing hidden typologies that could inform pathways to different child health and development outcomes [15]. Unlike traditional clustering methods, latent profile analysis captures qualitatively distinct combinations of higher and lower indicators [16], offering a more meaningful representation of built environment typologies. This method has been used in studies exploring the relationship between built environments and physical activity in children, adolescents, and adults [17, 18]. However, to our knowledge, no study has used latent profile analysis to identify built environment profiles and their relationship with early childhood developmental vulnerability.

Moreover, increasing social inequality has amplified concerns about the negative effects of socio-demographic disadvantage [19], which tends to accumulate in geographical areas [20]. According to the 2024 AEDC report, children in the most disadvantaged locations had more than twice the rate of developmental vulnerability compared to those in the least disadvantaged areas, with this gap widening over time [4]. Area-level disadvantage can result in limited access to important child-relevant services and play spaces, further contributing to poor developmental outcomes [21]. A more nuanced understanding of how socio-demographic disadvantage interacts with the built environment is thus needed.

Therefore, the present study sought to: (1) identify distinct built environment typologies of young children's neighbourhoods using latent profile analysis; (2) examine associations between these neighbourhood built environment typologies and early childhood development vulnerability; and (3) examine whether these associations differ by area-level disadvantage.

Methods

Study design and population

This study included a random sample of 5,356 children in the Perth/Peel region in Western Australia who participated in the 2012 AEDC. Children were sampled from suburbs with at least 25 children with AEDC data and residential addresses that could be assigned a latitude and longitude point [9]. Children were included in the analysis if they had complete neighbourhood environment data and at least one score on any of the five AEDC domains (n=5,066).

Data linkage

Data linkage of built environment measures to children's early development outcomes was performed by the Western Australian Government Department of Health's Data Linkage Branch, an accredited linkage agency. AEDC data were de-identified for linkage, involving the separation of identifying information (e.g., name, residential address) from AEDC scores and replacing it with an encrypted identifier ('linkage key'). Children's residential addresses (as recorded in the AEDC data set) were geo-coded by the linkage agency and provided to a Geographic Information Systems specialist research team member (who was not involved in subsequent data analysis) with the corresponding linkage key to create the neighbourhood built environment variables. These variables were then returned to the data linkage agency for removal of the geocoded residential address information and provided to a different research team member for merging with AEDC data using the linkage keys.

Child development

Child development data were obtained from the AEDC (2012 wave), a nationwide data collection occurring every three years at the time children commence full-time school [22, 23]. The AEDC uses the Australian version of the Early Development Instrument, which was adapted from the Canadian Early Development Instrument [24]. The instrument has evidenced reliability and validity and has been shown to predict later academic and wellbeing outcomes [25]. Teachers completed the AEDC survey based on their observations of the children in their class. The AEDC measures five domains of early child development: Physical health and wellbeing, Social competence, Emotional maturity, Language and cognitive skills (school-based), and Communication skills and general knowledge [22]. For each domain, children receive a score between 0 (low) and 10 (high) on a developmental spectrum. On the basis of national benchmarks established in the 2009 AEDC data collection cycle, children are classified as developmentally vulnerable if they fall below a cut point (approximately the lowest 10% of scores) on each domain. Domain cut-offs also account for age variations (i.e. a different cutoff depending on the child's age in years). In this study, a binary outcome variable was created to indicate whether a child was developmentally vulnerable on one or more of the five domains (yes/no). This matches the AEDC DV1 vulnerability summary indicator. Vulnerability on each domain was also considered; only children with valid AEDC domain scores [22] were included in domain-specific analyses. Children with special needs were not included within domain indicators because of the already identified substantial developmental needs of this group.

Neighbourhood built environment

Geographic Information Systems measures of the neighbourhood built environment were based on a 1600 m street network service area around each child's home. This 1600 m service area was chosen to represent the child's 'neighbourhood'. Although this service area is commonly used for adults, young children are typically accompanied by an adult when navigating their neighbourhoods. The service area for some child-relevant destinations (i.e., early childhood education and care, playgroups, child health centres, schools) was increased to 3 km or 10 km to account for their reduced presence. Details of the 17 neighbourhood built environment measures have been described previously [9, 26, 27] and are outlined in brief below.

Outdoor home-yard environment

Outdoor home-yard space was measured as the percentage of residential land within the service area that was not part of the total building footprint for the 1600 m service area. This variable was not able to be calculated for the child's home address due to the need to prioritise data security (i.e., potential participant identification) over data quality (i.e., individual residential level measures of the built environment).

Density and movement network

Residential density was measured as the number of residential dwellings per square kilometre of residential land. Measures of the movement network included street connectivity (the number of three-way - or more - intersections per square kilometre) and number of one-way nodes (cul-de-sacs, which are low traffic streets near home). Road traffic exposure (the percentage of minor roads carrying fewer than 3000 vehicles/day to total length of roads) was calculated as well as the number of transport stops (school bus, public bus, train) and presence/absence of a railway station.

Green space

Green space was measured as the presence of different sizes and types of green space, including: medium-large park (>0.5 to ≤5 ha); district-regional park (>5 ha); natural public open space; school grounds; club-pay facilities; and an above-average attractiveness park. Park attractiveness was derived from objectively measured park attributes (e.g., presence of trees, sporting facilities, amenities, water features, lighting) [28, 29]. The highest scoring park within the neighbourhood was categorised as above or below the average attractiveness score (67.58, SD=7.41) to indicate for each child whether an above average attractiveness park was present in their neighbourhood.

Child-relevant destinations

Child-relevant destinations included four measures: the number of playgroups, kindergartens and early childhood education and care centres within 3km of the child's home, and the number of child health centres within 10km of the child's home.

Sociodemographic variables

Child sex (male/female), Aboriginal/Torres Strait Islander status (yes/no), and speaking English as a second language (yes/no) were included from the AEDC dataset as covariates in analyses. Sociodemographic disadvantage was determined by the Socio Economic Index For Areas−Index of Relative Socio Economic Disadvantage (SEIFA) for the child's suburb of residence. SEIFA is measured with factors reflecting area-level disadvantage, such as low levels of educational attainment and high unemployment [30]. Scores were classified into quintiles, with the lowest quintile representing areas of greatest disadvantage. All sociodemographic data were obtained from the AEDC dataset.

Data analysis

Continuous or count neighbourhood built environment measures were standardised using z-scores. Latent profiles of the neighbourhood built environment and the association with child developmental vulnerability were determined using the three-step latent profile analysis approach with a distal outcome [31]. In the first step, the 17 neighbourhood built environment variables were entered into the latent profile analysis. Models with 1 through 10 profiles were examined to determine the optimal number of profiles. Model selection was based on the log-likelihood (LL); the Akaike Information Criterion (AIC), Consistent Akaike Information Criterion (CAIC), Bayesian Information Criterion (BIC), and sample-size adjusted Bayesian Information Criterion (SABIC) information criteria; entropy, interpretability, posterior probabilities, and profile size. Lower information criterion (LL, AIC, CAIC, BIC, SABIC) indicate better fit, while higher entropy (>0.8) and higher average latent posterior probabilities (>0.9) indicate better fit [32]. Characteristics of the emerging profiles were considered to determine whether profiles were qualitatively and quantitatively distinguishable and made conceptual sense within the Perth, Western Australia geographical context.

Second, children were assigned the most appropriate profile using proportional assignment adjusted for uncertainty when modelling profiles using the maximum likelihood correction method [31, 33].

In the third step, latent profiles were entered into logistic regression models to examine the association between profiles and AEDC outcomes, adjusting for child sex, Aboriginal or Torres Strait Islander status, and speaking English as a second language. Effect modification by socioeconomic status was tested by repeating each model, including an interaction term for SEIFA quintile-by-profile. Where the interaction was significantly associated with the outcome, logistic regression models stratified by SEIFA quintile were performed. Proportions of children developmentally vulnerable on the relevant AEDC domain within each latent profile are presented alongside model results (odds ratios, OR, and 95% CI). Analysis samples varied by outcome and are presented in the results tables (range n=5,027 to n=5,060). The three-step latent profile analysis with distal outcome was undertaken in LatentGOLD 6.0 using the cluster and step3 procedures [34].

Results

Children ranged in age from 52 to 79 months, with most children around 5 years of age. Half were male (50.4%, Table 1), 12% spoke English as a second language, and 3% were Aboriginal or Torres Strait Islander. About one-in-five children were developmentally vulnerable on at least one AEDC domain. Characteristics of the neighbourhood built environment features are presented in Table 2.

Table 1. Sample characteristics

	n (%)
Age	(range 52-79 months)
Sex (female)	2514 (49.6)
Aboriginal or Torres Strait Islander	174 (3.4)
Speaks English as a second language	620 (12.2)
Socioeconomic disadvantage quintile	
1, most disadvantaged	358 (7.1)
2	601 (11.9)
3	1215 (24.0)
4	1008 (19.9)
5, least disadvantaged	1883 (37.2)
Developmentally vulnerable on one or more domains	1095 (21.8)
Developmentally vulnerable on Physical health and wellbeing	442 (8.7)
Developmentally vulnerable on Social competence	402 (8.0)
Developmentally vulnerable on Emotional maturity	415 (8.2)
Developmentally vulnerable on Language and cognitive skills (school-based)	358 (7.1)
Developmentally vulnerable on Communication skills and general knowledge	444 (8.8)

Table 2. Characteristics of the built environment features.

	Mean (SD)	Range	n (%)
Outdoor home environment			
Neighbourhood home-yard space (m^2)	64.6 (7.8)	41.6-98.1	
Neighbourhood built environment			
Dwelling density	16.4 (5.0)	1.1-66.7	
Street connectivity	62.6 (21.1)	8.6-166.7	
One-way node count	50.9 (26.7)	2.0-150.0	
Road traffic exposure	26.1 (10.9)	0.1-77.5	
Transport stop count	41.0 (21.4)	0.0-121.0	
Presence of railway station			635 (12.5)
Green space			
Presence of medium/large park (>0.5 to ≤5 ha)			4920 (97.1)
Presence of district/regional park (>5 ha)			3964 (78.3)
Presence of natural public open space			4402 (86.9)
Presence of school grounds			4701 (92.8)
Presence of club-pay facilities			3161 (62.4)
Presence of above average attractive park			2790 (55.1)
Child-relevant destinations			
Playgroup count within a 3 km radius	3.8 (2.9)	0.0-15.0	
Early childhood education and care centre count within a 3 km radius	8.8 (5.0)	0.0-30.0	
Kindergarten/pre-primary count within a 3 km radius	6.1 (3.5)	0.0-21.0	
Child health centre count within a 10 km radius	9.9 (5.8)	0.0-26.0	

Latent profiles of neighbourhood built environments

Model selection and number of profiles

Information criterion improved with an increasing number of latent profiles, however improvements to fit were minimal beyond four profiles (Supplementary Table 1). Entropy declined to two profiles and thereafter increased, though generally remained high at around 0.9. Models with seven to 10 profiles contained at least one profile with fewer than 5% of the sample and/or profiles that were not conceptually distinct. Models with four to six profiles were examined further for interpretability. The model with five profiles was selected as the best fitting model. Profiles are interpreted below with respect to their key points of differentiation. Each of the five profiles was labelled based on its distinguishing built environment feature/s relative to the other profiles.

Characteristics of profiles

The first profile, 'Average neighbourhood', represented the largest proportion of children in the sample at 37.4%. This profile was characterised by average scores on most features, including the child relevant destinations, transport accessibility, and movement network. Given its balanced composition and high prevalence, this profile provides a baseline comparison for other profiles.

The second profile, 'Established neighbourhood', represented 22.5% of children. This profile was featured by the highest residential density, the greatest number of public transport stops, and the greatest access to child-relevant destinations compared to the other profiles. This profile also had the highest presence of green spaces, with the greatest presence of an above-average attractive park (85%), and a moderate level of traffic exposure, street connectivity, and one-way nodes.

The third profile, termed 'Low destinations and transport mix' (16.0%), had lower counts of child-relevant destinations, lower percentage of public open spaces (particularly district/regional park and club-pay facilities), as well as fewer transport stops and the lowest traffic exposure (similar to the next profile, 'Connected housing'). This profile had a moderate level of density, street connectivity, and one-way nodes.

The fourth profile, ‘Connected housing’ (14.3%), had the lowest home-yard space, highest street connectivity and one-way nodes, as well as the lowest traffic exposure. This profile had a relatively moderate level of child-relevant destinations and public open spaces.

The final profile, ‘Disconnected semi-rural’ (9.9%), had the lowest residential density, equally lowest public transport stops and child-relevant destinations (similar to the ‘Low destinations and transport mix’ profile). This profile had the lowest presence of built green spaces, particularly above-average attractive parks (5%). This profile also had the highest traffic exposure, the largest home-yard space, the lowest street connectivity, and one-way node count.

Overall, there were minimal differences between profiles for the presence of different park types and the presence of parks was generally high. Characteristics of each profile can be seen in Figure 1 and Table 3.

Table 3. Characteristics of the five built environment profiles.

	Average neighbourhood (37.4%)	Established neighbourhood (22.5%)	Low destinations and transport mix (16.0%)	Connected housing (14.3%)	Disconnected semi-rural (9.9%)
Outdoor home-yard environment					
Neighbourhood home-yard space (m^2), mean (SD)	65.4 (4.8)	63.1 (3.9)	61.1 (6.8)	58.6* (6.1)	79.6^ (8.6)
Neighbourhood built environment					
Dwelling density, mean (SD)	15.0 (1.6)	22.6^ (5.6)	15.4 (2.0)	16.7 (2.0)	9.0* (3.9)
Street connectivity, mean (SD)	55.0 (7.3)	61.1 (17.0)	72.4 (16.4)	91.2^ (25.4)	38.1* (13.4)
One-way node count, mean (SD)	63.1 (27.2)	35.1 (16.6)	43.2 (18.1)	68.4^ (25.0)	27.5* (13.2)
Road traffic exposure, mean (SD)	31.0 (9.2)	26.4 (7.6)	17.5 (8.1)	17.1* (8.5)	33.1^ (13.1)
Transport stop count, mean (SD)	41.4 (13.1)	68.8^ (17.4)	21.5 (7.5)	32.8 (9.4)	20.0* (13.5)
Presence of railway station, n (%)	237 (12.4)	316^ (27.8)	30 (3.7)	15* (2.2)	37 (7.5)
Green space					
Presence of medium/large park, n (%)	1883 (98.3)	1134 (99.8)	788 (95.8)	698 (99.9^)	417 (84.6*)
Presence of district/regional park, n (%)	1718 (89.7)	1040 (91.6^)	365 (44.4*)	614 (87.8)	227 (46.0)
Presence of natural public open space, n (%)	1676 (87.5)	776 (68.3*)	798 (97.0)	673 (96.3)	479 (97.2^)
Presence of school grounds, n (%)	1869 (97.6)	1134 (99.8^)	664 (80.7)	691 (98.9)	343 (69.6*)
Presence of club/pay grounds, n (%)	1151 (60.1)	967 (85.1^)	367 (44.6*)	410 (58.7)	266 (54.0)
Presence of above average attractive park, n (%)	1264 (66.0)	960 (84.5^)	240 (29.2)	300 (42.9)	26 (5.3*)
Child-relevant destinations					
Playgroup count within 3 km radius, mean (SD)	8.5 (3.3)	14.4^ (4.7)	4.1 (1.6)	9.9 (3.2)	3.3* (2.3)
Early childhood education and care centre count within 3 km radius, mean (SD)	6.0 (2.2)	10.4^ (2.8)	2.7 (1.3)	6.1 (1.8)	2.6* (1.6)
Kindergarten/pre-primary count within 3 km radius, mean (SD)	3.1 (1.7)	6.5^ (3.2)	1.4* (1.1)	5.4 (3.1)	1.9 (2.0)
Child health centre count within 10 km radius, mean (SD)	11.5 (4.6)	15.2^ (4.6)	4.9* (3.7)	6.2 (3.7)	5.0 (3.5)

^ Highest scores on each built environment feature; * Lowest scores.

Associations between built environment profiles and early child developmental vulnerability

Built environment latent profiles were associated with being developmentally vulnerable on at least one domain (Wald p=0.007). The odds of being developmentally vulnerable on at least one domain were significantly lower for the 'Established neighbourhood' profile compared with the 'Average neighbourhood', 'Connected housing', and 'Disconnected semi-rural' profiles (paired Wald tests p<0.05, Table 4). Overall, 18.3% of children in the 'Established neighbourhood' profile were developmentally vulnerable on one or more domains, compared with 22.5% of children in the 'Average neighbourhood' profile, 22.9 % of children in the 'Connected housing' profile, and 25.8% of children in the 'Disconnected semi-rural' profile. The proportion of children being developmentally vulnerable on at least one domain did not differ for all other paired profile comparisons (all p>0.050).

Latent profiles were also associated with being developmentally vulnerable on the Physical health and wellbeing domain (Wald p=0.036), with fewer children in the 'Established neighbourhood' profile being vulnerable (6.7%) compared to the 'Average neighbourhood' (9.3%) and 'Disconnected semi-rural' (11.2%) profiles. Built environment latent profiles were not associated with the Social competence, Emotional maturity, Language and cognitive skills (school-based), and Communication skills and general knowledge domains.

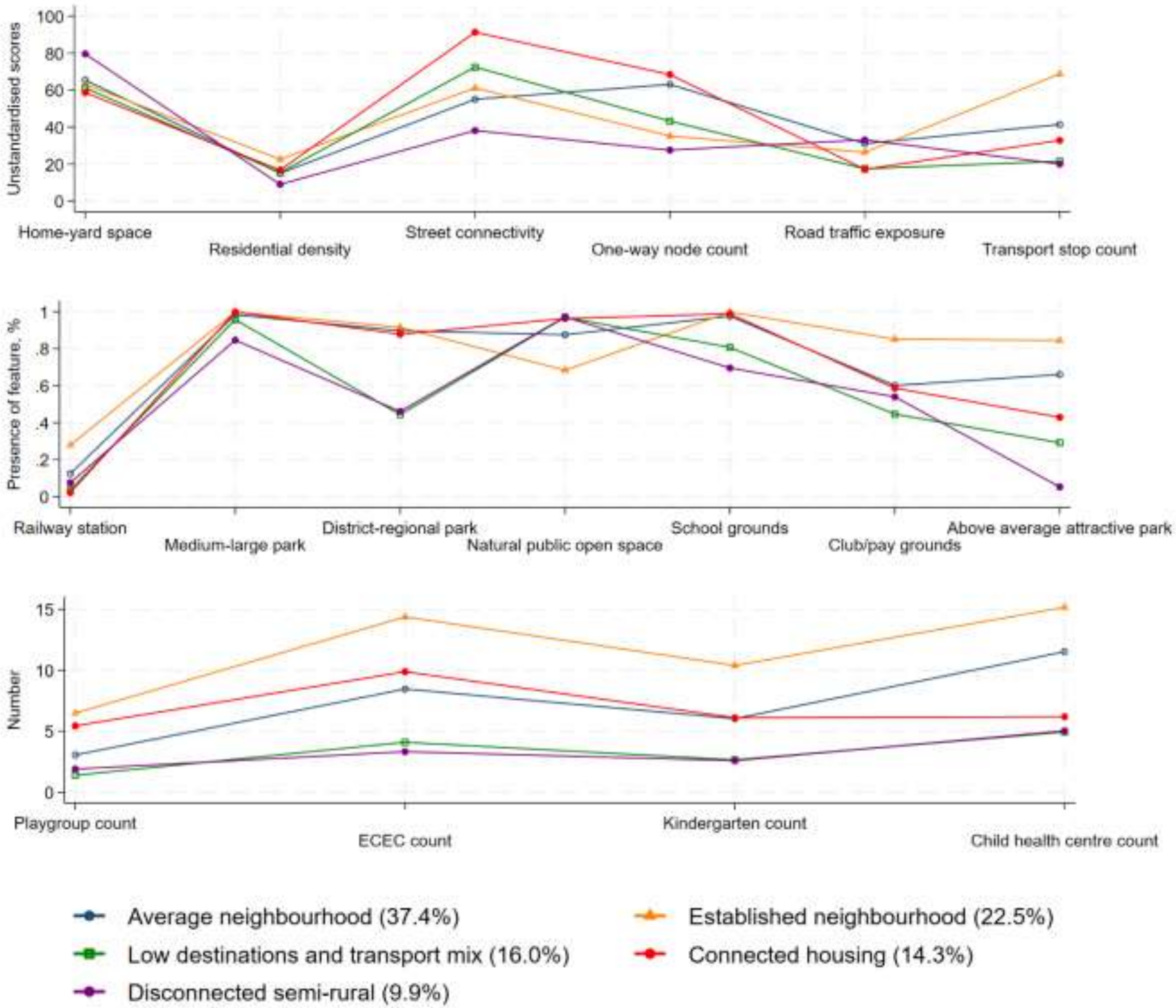
Table 4. Associations between built environment profiles and developmental vulnerabilities.

	DV1 (n=5027)		Physical health and wellbeing (n=5059)		Social competence (n=5055)		Emotional maturity (n=5036)		Language and cognitive skills (school-based) (n=5060)		Communication skills and general knowledge (n=5058)	
	%	OR (95% CI)	%	OR (95% CI)	%	OR (95% CI)	%	OR (95% CI)	%	OR (95% CI)	%	OR (95% CI)
Average neighbourhood (37.4%)	22.5	Ref	9.3	Ref	7.9	Ref	8.4	Ref	7.6	Ref	8.8	Ref
Established neighbourhood (22.5%)	18.3	0.8 (0.6, 0.9)	6.7	0.7 (0.5, 0.9)	7.3	0.9 (0.7, 1.2)	8.0	0.9 (0.7, 1.3)	5.7	0.7 (0.5, 1.0)	7.3	0.8 (0.6, 1.1)
Low destinations and transport mix (16.0%)	21.6	0.9 (0.8, 1.2)	9.1	1.0 (0.7, 1.3)	7.9	1.0 (0.7, 1.4)	7.2	0.8 (0.6, 1.2)	7.0	0.9 (0.6, 1.3)	8.8	1.0 (0.7, 1.4)
Connected housing (14.3%)	22.9	1.0 (0.8, 1.3)	8.3	0.9 (0.6, 1.2)	7.4	0.9 (0.6, 1.3)	8.9	1.1 (0.8, 1.5)	7.8	1.0 (0.7, 1.5)	10.8	1.3 (0.9, 1.8)
Disconnected semi-rural (9.9%)	25.8	1.2 (0.9, 1.5)	11.2	1.2 (0.9, 1.7)	10.5	1.4 (1.0, 1.9)	9.0	1.1 (0.7, 1.6)	7.3	1.0 (0.6, 1.5)	9.5	1.1 (0.8, 1.6)
p-value		0.007		0.036		0.270		0.760		0.310		0.150

Logistic regression models adjusted for child sex, Aboriginal or Torres Strait Islander status, and speaking English as a second language.
OR=odds ratio. CI=Confidence interval
DV1=Vulnerable on at least one AEDC domain
DV1: ‘Established neighbourhood’ significantly different (lower) to ‘Average neighbourhood’ (p=0.006), ‘Connected housing’ (p=0.018), ‘Disconnected semi-rural’ (p<0.001). No other significant between-group differences (all paired comparisons p>0.05).
Physical health and wellbeing: ‘Established neighbourhood’ significantly different (lower) from ‘Average neighbourhood’ (p=0.016), and ‘Disconnected semi-rural’ (p=0.003). No other significant between-group differences.

Socio-economic effect modification of the association between built environment profiles and early child developmental vulnerability

Latent profiles did not significantly differ by SEIFA quintiles for most outcomes (interaction $p>0.05$), except for being developmentally vulnerable on at least one or more domains (interaction $p=0.018$). In the third (middle) SEIFA quintile, children in the 'Established neighbourhood' profile had lower odds of being developmentally vulnerable on at least one domain compared with the 'Connected housing' profile, and children in the 'Disconnected semi-rural' profile had lower odds of being developmentally vulnerable compared with the 'Average neighbourhood', 'Low destinations and transport mix', and 'Connected housing' profiles (Table 5). In the least disadvantaged quintile, children in the 'Disconnected semi-rural' profile had higher odds of being developmentally vulnerable on at least one domain compared with all other profiles. There were no differences by built environment profile and developmental vulnerability on one or more domains for children in the most and second most disadvantaged quintiles, and the second least disadvantaged quintile.



321
322 Figure 1. Characteristics of the five latent profiles of children's neighbourhood built environments.

Table 5. Associations between built environment profiles and developmental vulnerabilities on at least one AEDC domain, stratified by SEIFA quintiles.

	Average neighbourhood (37.4%)	Established neighbourhood (22.5%)	Low destinations and transport mix (16.0%)	Connected housing (14.3%)	Disconnected semi-rural (9.9%)
Quintile 1, most disadvantaged (n=357)					
% children in profile	62.6	11.2	15.6	11.0	9.5
% vulnerable	28.9	39.0	25.1	-	31.2
OR (95% CI)	Ref	1.6 (0.7, 3.5)	0.8 (0.4, 1.8)	Not estimable	1.1 (0.5, 2.8)
p-value	0.660				
Quintile 2 (n=601)					
% children in profile	54.9	18.8	3.2	4.7	15.4
% vulnerable	27.8	25.5	34.9	49.2	27.4
OR (95% CI)	Ref	0.9 (0.5, 1.5)	1.4 (0.6, 3.6)	2.7 (0.9, 7.7)	1.0 (0.5, 1.8)
p-value	0.260				
Quintile 3 (n=1,198)					
% children in profile	38.4	22.1	14.0	17.6	8.0
% vulnerable	24.2	19.3	26.6	27.6	13.3
OR (95% CI)	Ref	0.7 (0.5, 1.1)	1.1 (0.7, 1.8)	1.2 (0.8, 1.9)	0.5 (0.2, 0.9)
p-value	0.035				
Quintile 4 (n=1,003)					
% children in profile	27.0	26.4	18.4	15.1	13.0
% vulnerable	22.1	18.5	24.6	20.8	27.8
OR (95% CI)	Ref	0.8 (0.5, 1.2)	1.2 (0.7, 1.9)	0.9 (0.5, 1.6)	1.4 (0.8, 2.3)
p-value	0.260				
Quintile 5, least disadvantaged (n=1,867)					
% children in profile	32.0	24.0	19.0	17.3	7.7
% vulnerable	16.5	13.9	15.0	17.9	29.0
OR (95% CI)	Ref	0.8 (0.6, 1.2)	0.9 (0.6, 1.3)	1.1 (0.8, 1.6)	2.2 (1.4, 3.4)
p-value	<0.001				

Estimates for ‘Connected housing’ within quintile 1 (most disadvantaged) are not available due to too few children in these categories.

Quintile 3: ‘Established neighbourhood’ significantly different (lower) to ‘Connected housing’ (p=0.034); ‘Disconnected semi-rural’ significantly different (lower) to ‘Average neighbourhood’ (p=0.029), ‘Low destinations and transport mix’ (p=0.023), ‘Connected housing’ (p=0.009). No other significant between-group differences (all paired comparisons p>0.05).

Quintile 5: ‘Disconnected semi-rural’ significantly different (higher) than ‘Average neighbourhood’ (p<0.001), ‘Established neighbourhood’ (p<0.001), ‘Low destinations and transport mix’ (p<0.001), and ‘Connected housing’ (p=0.007). No other significant between-group differences (all paired comparisons p>0.05).

Discussion

To our knowledge, no previous studies examining the associations between early childhood developmental vulnerability and the built environment have attempted to classify built environment features to better understand potential patterns of influence. This study aimed to address this gap by using a novel approach – Latent Profile Analysis – to determine whether the resulting neighbourhood profiles were associated with early developmental vulnerability, while also considering the role of area-level socioeconomic disadvantage. Five distinct profiles emerged, including 'Average neighbourhood', 'Established neighbourhood', 'Low destinations and transport mix', 'Connected housing', and 'Disconnected semi-rural'. Differences in children's developmental vulnerability were observed across these profiles. This suggests that the classification meaningfully captures built environment patterns relevant to early development, helping to address issues of collinearity among neighbourhood attributes by grouping them into interpretable patterns.

Children who lived in an 'Established neighbourhood' had the lowest rate of developmental vulnerability in any domain (18.3%), with particularly low vulnerability in the physical health and wellbeing domain (6.7%). One feature of this profile is the greatest number of child-relevant destinations, which is consistent with previous literature showing that better access to key learning, care, and health destinations was associated with improved early development outcomes [6]. For example, availability of daycare and kindergartens was associated with better physical development [9] and cognitive development [35]. While all profiles had a high presence of parks, the 'Established neighbourhood' profile had the highest presence of attractive parks. This aligns with past studies showing that while access to public green space generally has positive influences on early development [6], the quality or attractiveness of the space has a stronger impact [9]. Qualitative evidence similarly highlights the crucial role of park quality in influencing the actual usage of the space [36]. This profile also featured the greatest accessibility of public transport, as well as the highest dwelling density, which is consistent with previous studies linking these features to better physical development [9]. Accessible public transport is seen by parents as important for easy access to destinations and services, facilitating social networks, and local community participation, which are beneficial to early development [7].

Interestingly, the 'Established neighbourhood' profile had a moderate level of connectivity and one-way node counts, along with moderate to high traffic exposure. This could suggest that moderately connected and walkable streets might be sufficient to support positive early development outcomes when public transport is accessible, with slightly higher traffic exposure an acceptable trade-off in dense, active areas where resources and destinations are more concentrated. With past studies showing null associations between street connectivity, walkability, and early development [9, 26], these findings suggest that movement network features, like street connectivity, one-way nodes, public transport, traffic exposure, and density, may yield greater insights when investigated in combination rather than in isolation.

Children whose neighbourhood featured limited child-relevant destinations, few quality green spaces, limited public transport, but highest traffic exposure ('Disconnected semi-rural') had the highest rate of developmental vulnerability (25.7%) in any domain, and especially in the physical health and wellbeing domain (11.2%). Prior research has shown that low traffic exposure is associated with better independent mobility and physical activity [37], while high traffic exposure is associated with poorer development outcomes [9, 26]. The evidence suggests this profile reflects the most disadvantageous environment for early child development. Nevertheless, the 'Low destinations and transport mix' profile also had limited destinations, green spaces, and public transport, yet did not show poorer development outcomes. This suggests the buffering role of a connected and safe neighbourhood movement network when transport and destinations are not so accessible.

The 'Disconnected semi-rural' profile also had the largest home yards. While access to larger private yards and gardens has been frequently associated with better early social-emotional [12, 26] and physical development [38], the present analysis suggests that the benefits may be attenuated by other disadvantageous factors, such as limited local child-relevant destinations and public transport options.

Nevertheless, differences in yard sizes across profiles were relatively small. Further research is needed to clarify the role of home yards, particularly their interaction with neighbourhood built environment features and the impact on early child development.

The built environment profiles showed the strongest associations with early physical health and wellbeing. This may be because physical development is more directly influenced by the availability of the neighbourhood features measured in this study. For instance, access to parks and playgrounds [39], high density [40], and accessible public transportation [9], are associated with higher levels of children's physical activity. Child-relevant destinations such as childcare and playgroups also provide ample opportunities for outdoor play and activity [41], which directly supports physical development. In contrast, other developmental domains (e.g., social-emotional, cognitive, language) may be influenced by a wider set of factors that extend beyond just access to the destinations and services. For example, the quality of childcare, which reflects the learning experience children receive, has been shown to more strongly predict cognitive [42] and language development [43] than proximity. Studies also suggest pathways linking the built environment to these domains may be more indirect, through activity enjoyment, social interaction, and parenting [44]. Future research should continue to examine the pathways through which the built environment influences early development, particularly beyond physical health.

In general, more children were developmentally vulnerable in more disadvantaged areas, aligning with previous research highlighting inequity in early development [26]. Past studies have generally observed access to beneficial built environments is lower in more disadvantaged areas [7]. In this study, built environment profiles also varied by area-level socioeconomic disadvantage. In the least disadvantaged areas, associations between the profiles and early development were consistent with the overall findings. While high socioeconomic status is expected to support better outcomes, this finding suggests that the negative impact of low-mobility, resource-poor environments ('Disconnected semi-rural') may persist in these areas. In the middle disadvantage areas, the 'Disconnected semi-rural' and the 'Established neighbourhood' profiles appeared to be associated with better development. Similar patterns appeared in the second-most disadvantaged areas, although not statistically significant, possibly due to relatively smaller sample sizes. Future studies should explore potential protective factors that may buffer the effects of limited access to destinations and services in these lower socioeconomic status areas.

This inconsistency across socioeconomic status levels aligns with previous findings. For instance, Collyer and colleagues [45] observed that in high socioeconomic status areas, associations between the built environment and early development were in the expected direction, whereas unexpected associations appeared in low socioeconomic status areas. This discrepancy suggests that certain built environment features may function differently across socioeconomic contexts. For example, high density housing in high socioeconomic status areas may indicate access to more amenities and facilities, but is more likely to be associated with noise, crime/incivilities, and overcrowding in low socioeconomic status areas. Overall, more research is needed to understand how area-level disadvantage shapes the impact of the built environment on early development.

Strengths, limitations and future directions

This study has a number of strengths. First, is the application of AEDC linked data, which provides a broad coverage representative of Australia's urban-dwelling preschool children from a large metropolitan city. Second, examining the combined influence of built environment features on early child development moves beyond considering individual built environment effects, and is a promising start toward creating a child liveability index that further integrates built environment indicators. Third, while the current profile analysis considered the availability and accessibility of 17 built environment features, future research could include other relevant built environment attributes, such as perceived or objective quality of key built environment features, to further unpack the mechanisms underlying profile differences.

Limitations include the generalisability of the findings to children from more disadvantaged areas, those living in rural and remote communities, and non-Australian urban contexts. As a result, most children in this study had relatively good access to public green spaces, private yards, and lived in less disadvantaged suburbs. This may have reduced variability in built environment exposure and limited the detection of certain effects. Future research should expand the analysis to include more diverse cultural, geographic, and socioeconomic contexts.

Conclusion

This study classifies and identifies important neighbourhood built environment patterns associated with early childhood development vulnerability, highlighting how specific built environment profiles, particularly those characterised by greater access to child-relevant destinations, attractive green spaces, and public transport, are associated with lower developmental vulnerability, especially in the physical health and wellbeing domain. Conversely, profiles with poor movement network, low destination access, and higher traffic exposure were linked to worse developmental outcomes. These findings underscore the importance of considering the combined influence of built environment features, rather than isolated elements, in shaping early child development. This also provides direction for policy makers, practitioners, and parents to prioritise and determine the optimal environment for children and families. Further studies should continue to build on the derived profiles and explore the quality of built environment features, caregiver perceptions, and broader family and community-level factors to better understand the mechanisms linking neighbourhood environments to child development.

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Statement of Conflicts of Interest

The authors declare no potential conflicts of interest with respect to the research, authorship or publication of this research.

Ethics Statement

Ethics approval was granted by The University of Western Australia Human Research Ethics Committee (2021/ET000722).

Data Availability Statement

Australian Early Development Census data can be obtained via the Social Research Centre Australia (https://www.aedc.gov.au). All other data access enquiries should be directed to the Corresponding author.

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Supplementary Material

Table S1. Model fit statistics for latent profile analysis with 1 through 10 profiles.

Number of profiles	LL	BIC	AIC	CAIC	SABIC	Entropy
1	-87224.5	174679.3	174502.9	174706.3	174593.5	1.000
2	-78556.1	157581.3	157222.1	157636.3	157406.5	0.882
3	-74198.3	149104.6	148562.6	149187.6	148840.9	0.899
4	-71653.4	144253.8	143528.9	144364.8	143901.0	0.902
5	**-70092.1**	**141369.9**	**140462.2**	**141508.9**	**140928.3**	**0.909**
6	-68727.3	138879.2	137788.6	139046.2	138348.5	0.910
7	-67456.6	136576.7	135303.3	136771.7	135957.0	0.900
8	-66267.5	134437.3	132981.1	134660.3	133728.7	0.909
9	-65684.0	133509.1	131870.0	133760.1	132711.5	0.919
10	-64687.8	131755.6	129933.6	132034.6	130869.0	0.908

Bolded row indicates final model selection.
LL: log-likelihood.
AIC: Akaike Information Criterion.
CAIC: Consistent Akaike Information Criterion.
BIC: Bayesian Information Criterion.
SABIC: Sample-size-adjusted BIC.
Entropy: a measure of the precision of classification, higher value indicates greater precision.

Table S2. Posterior probabilities for each built environment profile.

Profile	% children in profile	Profile 1	Profile 2	Profile 3	Profile 4	Profile 5
Average neighbourhood	37.4	**0.944** **(0.111)**	0.016 (0.063)	0.012 (0.052)	0.021 (0.063)	0.007 (0.041)
Established neighbourhood	22.5	0.024 (0.074)	**0.973** **(0.083)**	0.000 (0.000)	0.004 (0.027)	0.000 (0.000)
Low destinations and transport mix	16.0	0.033 (0.091)	0.000 (0.003)	**0.920** **(0.138)**	0.027 (0.082)	0.020 (0.067)
Connected housing	14.3	0.035 (0.092)	0.004 (0.030)	0.024 (0.078)	**0.937** **(0.124)**	0.000 (0.003)
Disconnected semi-rural	9.9	0.021 (0.071)	0.000 (0.000)	0.024 (0.066)	0.002 (0.027)	**0.953** **(0.107)**

Diagonal cells (bold) indicate likelihood of being in assigned profile. Percentage of children in profile using proportional classification.