

من «مدينة صديقة للمشاة» إلى «مدينة تعتمد على السيارات»: التوسع العمراني العشوائي
والحياة اليومية في أربيل

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From Walkable City to Automobile-Oriented Life: Urban Sprawl and Everyday Life in Erbil

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المخلص

تركز البحوث المتعلقة بالشكل الحضري والتنقل عادةً على إحصاء الرحلات التي يقوم بها الأفراد، لكنها نادراً ما تحصى الرحلات التي يتوقفون عن محاولتها، أو تتساءل عن أعضاء الأسرة الذين يفقدون القدرة على الوصول وتلبية احتياجاتهم عند تمدد المدينة. تتناول هذه الدراسة كلا الجانبين؛ حيث يُعامل استخدام السيارة كمسار وليس كوجهة نهائية: فالشكل الحضري الملموس (المدرّك) يمثل المتغير المستقل، والاعتماد على السيارة يمثل المتغير الوسيط، بينما تتمثل النتيجة في "الحياة القائمة على السيارة" — والتي عُرِّفت هنا بالدرجة التي تصبح فيها

الأنشطة اليومية غير ممكنة إلا بوجود سيارة، وقيست جزئياً بما تخلت عنه الأسرة لكونه يتطلب مشقة كبيرة. تُوفر مدينة أربيل بيئة اختبار غير تقليدية؛ حيث تتجاوز فيها ثلاثة أجيال من الأشكال السكنية في وقت واحد ضمن المدينة نفسها، وتحت ظروف المناخ وأسعار الوقود ذاتها. شملت الدراسة عينة من 600 أسرة (بواقع 200 أسرة لكل جيل سكني). أظهرت النتائج أن الشكل الحضري الملموس يقلل من الاعتماد على السيارة ($\beta = -0.509$)، ويؤثر على الحياة اليومية بشكل رئيسي عبر هذا الوسيط: حيث بلغ الأثر غير المباشر -0.284 مقابل أثر مباشر قدره -0.211، مما يعني أن 57% من الأثر الإجمالي ينتقل عبر الاعتماد على السيارة. كما تعزز مسار الاعتماد على السيارة من 0.40 إلى 0.71 عبر الأجيال السكنية المتلاحقة. ولم يكن هذا الفقدان في القدرة على الوصول متساوياً بين الأفراد؛ إذ يصل الأطفال بمفردهم إلى 0.99 وجهة يومياً في النسيج السكني الأقدم، مقارنة بـ 0.48 وجهة فقط في النسيج الأحدث. وبذلك، فإن التمدد العمراني في أربيل لم يقلل من إمكانية الوصول بشكل عام، بل أعاد توزيعها لصالح من يقودون السيارات فقط.

Abstract: Research on urban form and travel counts the journeys people make. It rarely counts the ones they stop attempting, or asks who in a household loses reach when a city disperses. This study takes up both. Car use is treated as the path rather than the destination: perceived urban form is the antecedent, car reliance the mediator, and the outcome is automobile-oriented life, defined here as the degree to which ordinary activities work only with a car and measured partly by what a household gave up as too much trouble. Erbil affords an unusual test: three residential form generations stand at once inside one city, one climate and one fuel price. Six hundred households were sampled, 200 per generation. Perceived form lowers car reliance ($\beta = -0.509$) and reaches daily life mainly through it: the indirect path is -0.284 against a direct effect of -0.211, so 57 per cent of the total effect travels through the car; the car-reliance path strengthens from 0.40 to 0.71 across the generations. The loss is not shared. Children reach 0.99 places alone a day in the oldest fabric, 0.48 in the newest. Sprawl in Erbil did not reduce access; it reallocated it to those who drive.



1. Introduction

In the quarters that fall away from the Citadel mound, a household's day is short in the literal sense. Bread comes from the end of the lane, the school is four minutes on foot, the covered bazaar absorbs most of what a family needs in an afternoon, and the walk between them is where people meet each other. None of it was designed as walkability. It is what a city looks like when it is laid out before cars, and Erbil kept that shape for a very long time.

Two decades changed it. After 2003 the city grew outward along a widening set of ring roads, and the growth took a form the old fabric had never carried: gated compounds, villa districts at low density, shopping consolidated into malls at junctions, and long arterials that are hard to cross on foot and unpleasant to walk beside in July. The households that moved there did not stop shopping, visiting or working; they began doing all of it from behind a windscreen. A day once measured in minutes of walking is now measured in trips.

That sequence is familiar to urban research. The connection between dispersed land use and car dependence is among the better-evidenced relationships in the field, established first as an international comparison of density and fuel use [1,2] and then refined into a body of elasticity estimates linking density, diversity, design and destination access to how much people drive [3,4].

What the same literature has been slower to say is what the relationship does to people. Automobility is a system rather than a set of individual choices, binding industry, infrastructure, land and habit together until driving stops being a decision and becomes a condition of taking part in the city [5,6]. The empirical work that would show this at the scale of a household's day sits almost entirely outside the region, in North America, western Europe, Australia and the large cities of East Asia, and the assumption that it travels to a city like Erbil is convenient rather than tested [7,8].

Erbil has begun to appear in that literature. Its mobility system has been described as following an eastern rather than a western path, with a car fleet that outgrew the network carrying it and almost no formal public transport to absorb the difference [9]. Accessibility work has shown how unevenly the large green spaces serve residents once travel time is measured by car [10], and studies of post-war mass housing have documented how fast new districts were produced and how little that production answered to environmental considerations [11]. None of this asks what the change did to the texture of a day, which is the part

residents talk about first and the link reviews of urban form and quality of life keep naming as the weakest [12].

This paper takes that question directly, and it makes one structural change to the usual model in order to do so. Car use is not the outcome here. It is the path. Perceived urban form is the antecedent, car reliance is the mediator, and the outcome is a construct this study defines and measures: automobile-oriented life, the degree to which ordinary activities have been rearranged so that they only work with a car. The distinction matters because ownership and reorganisation are not the same thing. A household may own two cars and still buy its bread on foot; another may own one and find that nothing in its week survives the car being unavailable.

Three questions follow. First, does perceived urban form predict how far daily life has been reorganised around the car, and how much of that effect travels through car reliance rather than around it? Second, does the pattern differ across residential fabrics built in different eras but inhabited at the same time? Third, and consequently, is the useful lever for policy the street or the traffic?

The contribution is fourfold, and each part is set against what the field currently does rather than asserted on its own.

First, the model is re-ordered. Research on form and travel almost always places car use at the end, as the thing to be explained. Here it sits in the middle, and what is explained is the reorganisation of ordinary life around it. That is a testable difference, not a rhetorical one: it predicts that most of the effect of form should arrive indirectly, and the estimate can refuse the prediction.

Second, the outcome counts what did not happen. A resident who has stopped attempting a journey reports no difficulty with it, so an instrument that counts trips made records a constrained household and an unconstrained one identically. Respondents here were asked which activities they had meant to carry out and abandoned because getting there was too much trouble, and that count enters the outcome construct alongside the share of activities requiring a car.

Third, the comparison holds the city constant and varies the fabric. Cross-city work compares places that differ in climate, fuel price, income and planning regime at the same time, and the form effect has to be disentangled from all of them. Erbil carries three residential generations side by side under one of each, so the fabric varies while the context does not.

Fourth, the results report who lost reach rather than how much reach was lost on average. Two indicators are directed at people who do not drive



and cannot simply absorb a longer trip: children, and adults in the household without a licence or without access to the vehicle. A mean holds these losses and conceals them, which is why they are measured separately and reported separately.

2. Urban form, car dependence and the texture of daily life

This section moves from the link between dispersed form and car dependence, to what walking does once it happens, to where Erbil sits against the regional evidence.

2.1. Sprawl, car dependence and the built environment

Sprawl is hard to measure because it is several things at once. The durable treatments break it into dimensions rather than one quantity: density, continuity, concentration, clustering, centrality, nuclearity, mixed use and proximity, each measurable and none sufficient alone [13]. Indices built on that logic connect sprawl to travel outcomes across many urbanised areas [14], and landscape ecology has set out criteria a sprawl measure should satisfy before it is trusted [15]. Where ground data are thin, remote sensing carries much of the measurement burden [16].

The economic account of why cities sprawl is largely uncontested: rising incomes, falling transport costs and edge land prices push development outward, and the market gets the balance wrong because several costs of that move are not paid by the people making it [17]. The direction of change is not fixed, and some metropolitan areas have become measurably more compact over a decade [18]; a review of the accumulated evidence finds compactness associated with a consistent set of outcomes across health, safety and mobility [19].

The link from form to travel has been quantified repeatedly. The synthesis that first pulled the estimates together found consistent but modest elasticities, with destination accessibility doing more work than local density [20], and the meta-analysis that followed confirmed the pattern across a much larger body of studies [3]. People who like walking also move to walkable places, so the association may be preference wearing the costume of causation, and the objection has been taken seriously. Quasi-longitudinal designs asking about behaviour before and after a move find an effect of form that survives controlling for attitude [21], reviews of dozens of self-selection studies conclude the same [22], and the methodological literature has clarified what self-selection does and does not undermine [23]. Work in Nordic cities argues that the causal claim is defensible when the mechanism is specified rather than assumed [24,25].

Not everyone is convinced, and the sceptical readings are worth keeping in view because they discipline the claim. A re-analysis of the meta-analytic data argued that compact development's effect on driving is smaller than commonly reported once study quality is weighted [26], and a direct test of the density and automobile dependence thesis found that the relationship holds but that density is a proxy for a bundle of things rather than the operative variable itself [27]. The compact-city literature has its own long argument about whether density delivers what is claimed of it socially [28], whether form is the right object of policy at all [29], and how the sustainable urban form concepts relate to one another [30,31]. This paper takes from it one working position: form matters, but through mechanisms that have to be named.

2.2. Walkability and everyday life

Walkability entered the field as a measurable property of neighbourhoods, first as environmental correlates of walking drawn from three separate literatures [32], then as an index built from density, land-use mix, connectivity and retail floor area [33], and as a perceived counterpart to those objective measures, since what the resident registers is what governs the decision to walk [34]. The perceived instruments matter here more than the objective ones. A street can score well on connectivity and still be unwalkable at four in the afternoon in August.

The concept has been contested throughout. Walkability names at least three different things — the physical possibility of walking, the pleasantness of it, and the destinations it reaches — and studies rarely say which they mean [35,36]. Design work has approached it from the street rather than the index [37], and behavioural work has arranged the requirements into a hierarchy in which feasibility, accessibility, safety, comfort and pleurability are satisfied in order [38]. Attempts to measure what observers respond to but indices miss have made some of that judgement operational [39], and participatory methods show that walkability differs sharply by who is asked [40].

What walking does, once it happens, reaches beyond transport. Walkable neighbourhoods have been associated with higher social capital [41] and with a sense of community that survives controlling for the kind of people who choose them [42]. Urban form has been linked to social well-being through ordinary encounters [43] and, in compact settings, to subjective well-being through pathways that do not all point the same way [44]. Cross-national evidence connects environmental attributes to measured activity across four continents [45], and trip experience contributes to well-being independently of destination [46,47].



Read together, these strands suggest something the transport framing tends to lose. The car does not simply substitute for walking; it reorganises the day around itself, changing when things happen, with whom, and whether they happen at all [48]. Transport disadvantage falls hardest on those who cannot drive or cannot afford to [49], the distributional consequences of car-oriented street space have been argued as a matter of justice rather than efficiency [50], and the mismatch between where low-income women live and where they can reach has been documented as a planning failure rather than a personal one [51]. The sustainable mobility paradigm reframes the problem as reducing the need to travel rather than the speed of it [52], the frame this paper adopts. Figure 1 puts that idea in a form the rest of the paper can carry. The old city held its residents on a short tether, and because everything sat inside a walk the tether never pulled. Dispersal did not cut it. It lengthened it enormously and made it rigid, so that reach expanded and independence contracted at the same time. The car is that rigid tether, and the figure draws what a day reaches on foot and by car from a home in each of the three fabrics described below.

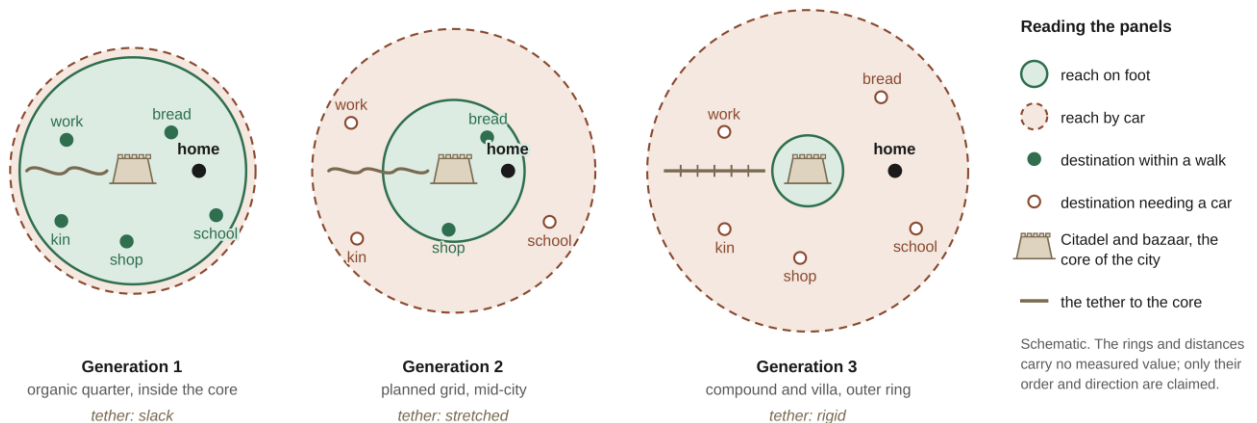


Figure 1. The walkable core contracting and the car reach expanding across the three form generations. Each panel is centred on the Citadel, the home sits at its generation's distance from it, and a destination is filled where it falls within the walk. *Source: Authors.*

2.3. The Erbil case and the gap

Regional evidence is growing but remains narrow. Recent work in Saudi Arabia has modelled walkability projections for Riyadh and produced walkability indicator sets tailored to Gulf street conditions through expert consensus [53,54]. Both are useful, and both stop at the street. Neither asks what car orientation does to the day, and neither is set in a city where three residential fabrics from three eras remain in simultaneous use. Comparative evidence from elsewhere shows that suburban density alone

does not settle mode choice, since high-density suburbs can still generate car commuting when the destinations are not where the density is [55], which is precisely the configuration Erbil has built.

Three things make the omission worth repairing. The outcome variable in almost all of this work is travel, and travel is a poor proxy for daily life: two households with identical vehicle-kilometres can have very different days if one drives by choice and the other because the alternative was removed. The rapidly motorising city is also not a late version of the slow one. Erbil acquired its fleet in about twenty years without the intervening decades of tram, bus and rail, so there is no earlier public transport layer for policy to fall back on [9]. And regional walkability research has concentrated on assessment instruments rather than consequences, producing careful audits of streets whose effect on anyone's week is unmeasured [53,54].

The gap is therefore specific rather than general. The relationship between form and driving is established; what is missing is a measured account of the reorganisation of ordinary life, in a rapidly motorised city where the walkable alternative is not hypothetical but physically present a few kilometres away. Erbil allows that comparison inside one municipality. Five hypotheses follow, shown in Figure 2. Perceived urban form is expected to reduce car reliance (H1) and to reduce automobile-oriented life directly (H2); car reliance is expected to increase automobile-oriented life (H3); the effect of form on automobile-oriented life is expected to run substantially through car reliance (H4); and the strength of these relationships is expected to differ across form generation (H5).

Table 1 sets this out against the studies the paper builds on. Two traditions run down it and never meet. One measures the fabric carefully and then counts only the journeys that were made; the other asks who is shut out and does not measure the fabric they live in. No row carries a mark in both of the last two columns until the last row, and that is the position this study occupies. It is a positioning table rather than a systematic review: the studies are those cited in this section, chosen to span the traditions the argument draws on, and no exhaustive search is claimed.

Table 1. What the studies this paper builds on measured, and what they did not. *Source: Authors.*

Study	Setting	Form measured as	Outcome modelled	Not attempted	Who loses reach
Newman	& 32	world	Gross density	Fuel use per	—



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Study	Setting	Form measured as	Outcome modelled	Not attempted	Who loses reach
Kenworthy [1]	cities		person		
Cervero & Kockelman [4]	Bay Area, US	Density and design	Trip rates and mode	—	—
Ewing & Cervero [3]	Meta-analysis	Built-environment Ds	Vehicle distance, walking	—	—
Handy et al. [21]	N. California, US	Neighbourhood type	Driving, net of preference	—	—
Næss [24]	Nordic cities	Distance to the centre	Travel distance and mode	—	—
Stevens [26]	Meta-analysis	Compact development	Driving	—	—
Ewing et al. [27]	US urban areas	Density	Automobile dependence	—	—
Frank et al. [33]	Seattle, US	Walkability index	Walking and activity	—	—
Cerin et al. [34]	US and Australia	Perceived walkability	Walking	—	—
Mouratidis [44]	Oslo, Norway	Compact vs sprawl	Subjective well-being	—	—
Lucas [49]	UK, review	Not measured	Social exclusion	—	✓
Blumenberg [51]	US	Not measured	Access, low-income women	—	✓
Alsabbagh [9]	Erbil, Iraq	Mobility paradigm	Mode choice and travel	—	—
Hassan et al. [10]	Erbil, Sulaimaniyah	Network and land use	Travel time to green space	—	—
This study	Erbil, Iraq	Perceived form	Daily life reorganised	✓	✓

**Note: A positioning table across the traditions the argument draws on, not a systematic review: the studies are those cited in this section and no exhaustive search is claimed. Not attempted means the study counted activities a household gave up; who loses reach means it reported the loss by person rather than as an average. A tick marks a column a study measured, a dash one it did not.*

boxes with rounded corners are latent variables; small squares are the observed items that measure them

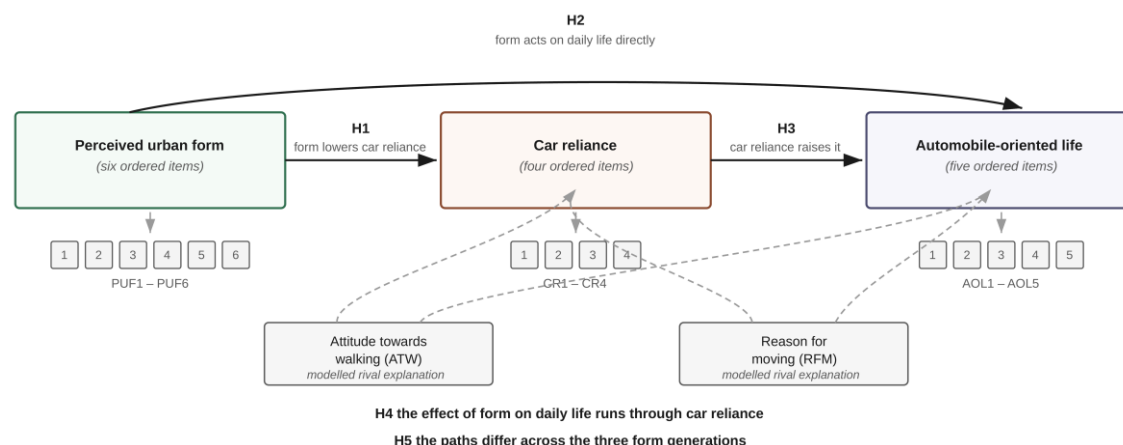


Figure 2. Conceptual model, measurement structure and hypotheses.
Source: Authors.

3. Materials and Methods

The design rests on three decisions, in this order: where the sample is drawn, what each respondent is asked to remember, and how the model is estimated.

3.1. Study area and the generational-form design

Erbil is the capital of the Kurdistan Region of Iraq and one of the oldest continuously inhabited places in the world. Its plan is legibly concentric: the Citadel occupies a tell at the centre, the covered bazaar wraps around its foot, and successive rings have been added outward, each built to the standards of its decade. That layering is ordinary in the region's historic cities. What is less ordinary is how recent and how legible Erbil's version is: the three residential fabrics were built within living memory of one another, remain in full residential use within a few kilometres, and sit under one administration, one climate, one fuel price and one broad culture.

The first generation is the organic quarter: narrow streets laid before motor traffic, plots wrapped tightly around courtyards, retail dispersed through the fabric rather than gathered into centres, and a street network whose intersections are frequent and whose blocks are short. The second is the planned grid neighbourhood produced from the 1970s onward: moderate density, a regular street layout, local shops at corners and on spines, and enough width for cars without the street being surrendered to them. The third is the post-2003 landscape of walled compounds, low-density villa districts and mall-anchored commercial nodes, arranged along and between the ring roads, in which the walking network frequently terminates at a gate or an arterial. Figure 3 shows the arrangement schematically.

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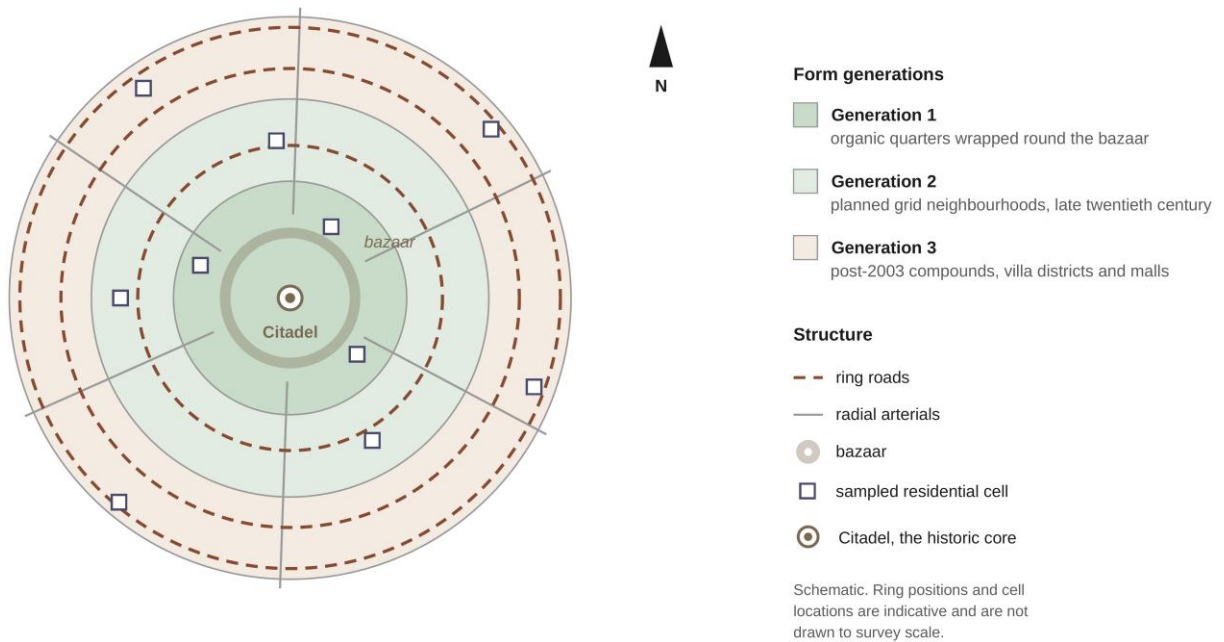


Figure 3. Erbil's concentric structure, its ring roads and the three form-generation strata. *Source: prepared by the authors from [9–11].*

The sequence in which those rings were added matters, because it separates morphology from date of arrival. The first two generations grew slowly, when edge land was not cheap to service and most households owned no vehicle. The third arrived with capital, easy vehicle purchase, and a development model whose residential product is a walled enclave sold on security and prestige rather than on location [11]. The result is the pattern sprawl measurement exists to catch [16]: a built-up area expanding faster than the population inside it, lowering average density even as the centre stayed occupied, driven by the post-2003 housing wave documented for Erbil [11]. The three fabrics are therefore three different products rather than three points on one trajectory.

Sampling was stratified by form generation rather than by administrative district, and this is the move on which the design rests. Administrative boundaries in Erbil do not follow morphology, and a single district can hold two of the three fabrics, which is why district-level analysis blurs the contrast that matters. Stratifying by form converts one city into a controlled comparison and removes, by construction, most of what cross-city studies have to argue away: fuel taxation, climate, licensing, vehicle price, national income and norms around walking are the same for every respondent. What varies is the fabric and the household inside it. Table 2 defines the strata and reports the realised sample.

Table 2. The three form generations, the stratum definition and the realised sample. *Source: Authors.*

Generat ion	Fabric	Street pattern	Retail pattern	Sample n	With child under 16
G1	Organic quarter	Short blocks, dense intersections	Dispersed in the fabric	200	160
G2	Planned grid	Regular grid, continuous footways	Corner and spine shops	200	163
G3	Compound and villa	Long blocks, gated or cul-de-sac	Consolidated in malls	200	151
Total				600	474

**Note: The last column is the realised door quota of households containing someone under 16; the rule was at least 140 per stratum.*

Delineation used the current built-up extent, with block size, intersection density and through-connection at the edge of the residential cell as the assignment criteria. Ambiguous cells, typically older grid neighbourhoods partly walled off, were assigned to the generation whose network behaviour they now display rather than to their decade of construction, since it is present-day behaviour that governs how a resident moves.

3.2. Instrument, constructs and sampling

Each respondent supplied two kinds of evidence, and the pairing is deliberate. The first is perceived urban form, measured on an instrument adapted into Sorani Kurdish from the neighbourhood walkability tradition [32–34], covering residential density, land-use mix and destination access, street connectivity, walking infrastructure, shade and thermal comfort, and traffic and personal safety. Shade is a separate dimension rather than part of comfort, because in Erbil's summer it is a precondition rather than a refinement. Items were translated, back-translated and piloted with 20 residents.

The second is an activity-tether recall for one ordinary weekday. Respondents reconstructed the previous working day and reported, for each out-of-home activity, whether it was reached on foot, by car as driver or passenger, or by shared taxi. They were then asked the question usually left out: whether anything they had meant to do was abandoned because getting there was too much trouble. Abandoned activity turns everyday life from a mood into something countable, and it is where the constraint becomes visible, since a resident who has stopped attempting a journey reports no difficulty with it.

Automobile-oriented life is measured by five indicators, each of them a different trace of the same underlying tendency: the share of activities



requiring a car, the count of abandoned activities, whether the household's routine survives the car being unavailable for a day, whether children reach school or friends independently, and whether adults in the household without a licence or without access to the vehicle conduct their day at the same radius as those with it. The counts are recoded into ordered bands before estimation so that all five enter the model on the same footing: the car share into five bands running from none to above three quarters of the day's activities, the abandoned count into none, one, two and three or more, and the remaining three indicators as the three-category answers they were asked as. The construct is specified as a latent variable measured by those five ordered indicators, a reading their loadings of 0.77 to 0.83 and an omega of 0.90 support. The full questionnaire and codebook accompany the data held by the corresponding author.

Residential self-selection is modelled as a rival explanation rather than acknowledged in the limitations. Two constructs enter for that purpose: attitude towards walking, and the stated reason for choosing the dwelling, coded from a fixed list covering price, space, security, family proximity, prestige and access to work. The form effect is therefore estimated net of the preference that placed the household where it is [21–23]. Table 3 gives every construct, its items, its scale and the instrument each was adapted from.

Table 3. Constructs, indicators, measurement scale and source. *Source: Authors.*

Construct	Items	Response scale	Adapted from
Perceived urban form	PUF1– PUF6	Five-point agreement	Walkability instruments [32–34]
Car reliance	CR1–CR4	Five-point agreement	This study, after [2], [5]
Automobile-oriented life	AOL1– AOL5	Ordered bands from counts	Written for this study
Attitude towards walking	ATW1– ATW3	Five-point agreement	Self-selection work [21–23]
Reason for moving	RFM1	Fixed category list	Written for this study

The sampling frame was households in occupied residential cells across the three strata. Interviewing continued in each stratum until two hundred completed forms were reached, which is why the realised strata are equal: of roughly 700 households approached, 600 interviews were completed and passed screening, a consent question followed by a completeness check, as Table 2 reports. One adult answered each interview, in 559 of the 600 cases answering for the whole household. Interviewers carried

two door quotas, because two outcome indicators cannot reach every household: at least 140 households per stratum containing someone under 16, met at 160, 163 and 151, and a cap that stopped any stratum filling with households in which every adult drives. Fieldwork ran in June 2026, face to face, since postal and online frames under-represent the households whose mobility is most constrained.

3.3. Analytical strategy

The model is estimated as a structural equation model with latent variables, on software that is free and open-source from end to end. It also improves the paper, because a design whose central claim is an indirect effect benefits from an estimator that reports an absolute test of model fit and a likelihood-based comparison between nested models.

The five-point items are treated as ordered categories rather than as interval scores. With five categories and skewed distributions, treating the responses as continuous biases the loadings downward and the standard errors with them [56,57]. Estimation therefore runs in two stages. Every pair of indicators is related by a polychoric correlation, each item's thresholds read from its own marginal distribution and the correlation found by maximising the likelihood of the joint table; pairs use the cases valid for that pair, so an indicator that cannot reach every household costs only the pairs it touches: the child-mobility indicator is answerable in the 474 households containing someone under 16, the non-driver radius in the 531 holding such an adult, and every other item reaches all 600. Because the pairs differ in the cases they use, the chi-square and the indices derived from it are scaled on the effective sample size the pairwise estimation leaves, 574.6, rather than on the 600 respondents. The measurement model and the structural model are then fitted to that matrix by minimising the maximum-likelihood discrepancy, with residual variances set so that every diagonal element stays at unity. The chi-square and the indices derived from it treat the polychoric matrix as an observed covariance matrix and carry no scaling correction [58], so they are read descriptively; inference about every parameter rests instead on percentile intervals from resampling the whole procedure, correlations included, which carries the uncertainty of the first stage into the second instead of treating the correlations as known.

The analysis follows the two-step logic: the measurement model is established first, and no structural path is interpreted until it holds [59]. Fit is judged on the comparative fit index, the Tucker-Lewis index, the root mean square error of approximation and the standardised root mean square residual, read together rather than against a single cut-off [60].



Reliability is reported twice, as Cronbach's alpha for continuity with the literature and as McDonald's omega, which does not assume equal contributions and is the better estimate where loadings differ [61].

Discriminant validity is tested rather than inspected. For each pair of constructs the model is fitted twice, once with the correlation between them free and once with it fixed to unity, and the difference in the chi-square is tested against the difference in degrees of freedom [59]. A pair that cannot be distinguished this way is reported as such rather than rescued by dropping an item.

Common method variance is addressed before estimation as well as after it. Procedurally, the two instrument blocks are separated in the questionnaire, anonymity is assured, and the tether recall is anchored to a named day rather than to a general impression [62]. Statistically, a single unrotated factor is extracted across all items and the share of variance it carries is reported, and variance inflation factors are computed across the item set.

The indirect effect is tested directly rather than inferred from a sequence of significance tests. Percentile confidence intervals come from five thousand bootstrap resamples of the whole model, which makes no normality assumption about the product of two coefficients [63], and the result is read as a type of mediation rather than as its presence or absence [64]. Resamples that fail to converge are dropped and counted, and the count is reported beside the interval.

Before the paths are compared across the three generations, measurement invariance is tested by fitting the model with loadings free in each stratum and again with loadings held equal, judged on the change in the comparative fit index rather than on the chi-square difference, which is oversensitive here [65]; the comparability of the item thresholds is examined separately, each stratum allowed its own location and dispersion on the latent scale. Only where invariance holds are the paths compared, and the comparison is a permutation test that relabels respondents across strata 500 times and rebuilds the null distribution of the between-group spread. The stratum comparison is then repeated with two observed covariates, household income as a five-band self-placement with declined answers excluded, and the number of vehicles available to the household; the vehicle count overlaps on purpose with what car reliance measures, so a difference that survives it is not a household-resources story. Out-of-sample accuracy is assessed by ten-fold cross-validation of a regression predicting the standardised outcome composite from the form and car-reliance composites.

Everything runs in Python. The correlations, the measurement model and the structural solution are written directly on NumPy [66] and SciPy [67] rather than taken from a package. Ready-made ordinal routines exist, in Python [68] and in R [69]; they were set aside because the resampling has to wrap the whole procedure, first stage included. Data handling uses pandas [70], reliability in the second implementation comes from Pingouin [71] and its cross-validated regressions from statsmodels [72], and the diagnostic plots are drawn with Matplotlib [73]. Versions are pinned in the released requirements file. Every headline statistic is computed twice, by implementations differing in their quadrature, their search, their parameterisation of the factor correlations and their optimiser, and the two must agree before a number enters this manuscript. The pipeline, the fixed seed and the run log accompany the response file held by the corresponding author, so a reader with the data can reproduce every figure in this paper, in the spirit of [74].

4. Results

The reporting order was fixed before the survey ran: measurement first, and no structural coefficient read until the measurement model holds. Every value below was computed twice, by two implementations sharing no code.

4.1. Measurement model

Standardised loadings are reported in Table 4 with Cronbach's alpha, McDonald's omega and the average variance extracted for each construct. All eighteen items were retained; the weakest standardised loading is 0.757, on the street-connectivity item PUF3.

Table 4. Measurement model: standardised loadings, internal consistency and convergent validity. *Source: Authors.*

Construct	Indicator	Loading	SE	p	α	ω	AVE
Perceived urban form	PUF1 residential density	0.782	0.022	< 0.001	0.879	0.899	0.598
	PUF2 land-use mix	0.798	0.020	< 0.001			
	PUF3 street connectivity	0.757	0.023	< 0.001			
	PUF4 walking infrastructure	0.774	0.021	< 0.001			
	PUF5 shade and thermal comfort	0.762	0.023	< 0.001			
	PUF6 traffic and personal safety	0.764	0.022	< 0.001			



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Construct	Indicator	Loading	SE	p	α	ω	AVE
Car reliance	CR1 share of trips by car	0.787	0.023	< 0.001	0.836	0.863	0.612
	CR2 licence and vehicle access	0.766	0.024	< 0.001			
	CR3 perceived need for the car	0.814	0.022	< 0.001			
	CR4 substitutability, reversed	0.759	0.026	< 0.001			
Automobile-oriented life	AOL1 activities needing a car	0.832	0.021	< 0.001	0.843	0.897	0.634
	AOL2 activities abandoned	0.794	0.025	< 0.001			
	AOL3 a car-free day still works	0.803	0.024	< 0.001			
	AOL4 children move alone	0.767	0.030	< 0.001			
	AOL5 radius without a car	0.784	0.026	< 0.001			
Attitude towards walking	ATW1 enjoyment of walking	0.805	0.024	< 0.001	0.821	0.852	0.659
	ATW2 willing to walk 10 minutes	0.769	0.026	< 0.001			
	ATW3 walking preferred	0.858	0.022	< 0.001			

**Note: α is Cronbach's alpha, ω is McDonald's omega, AVE is the average variance extracted; loadings are standardised and their standard errors come from 5,000 resamples. RFM1 is a single observed item used in the self-selection check of Section 4.2, so it carries no loading.*

The measurement model as a whole returned a chi-square of 254.5 on 129 degrees of freedom ($p < 0.001$), with a comparative fit index of 0.978, a Tucker-Lewis index of 0.974, a root mean square error of approximation of 0.041 and a standardised root mean square residual of 0.032. These are read together rather than against a single cut-off [60]. The rule was to drop an item only where its loading was weak and its content duplicated a neighbour, and none met it; dropping an item that carries a distinct part of a construct buys fit at the cost of validity, which is the wrong trade. Discriminant validity is reported in Table 5 as a test rather than as a comparison of numbers. For each pair of constructs the model was fitted with the correlation between them free and again with it fixed to unity, and the change in the chi-square was tested [59]. Every pair was distinguishable at the five per cent level, and the heterotrait-monotrait

ratios in the same table stay under the 0.85 mark. The largest factor correlation is 0.698, between car reliance and automobile-oriented life, close enough to earn the robustness check reported with the structural model. On common method variance, a single unrotated factor carried 41.5 per cent of the total variance and the largest variance inflation factor was 2.72; the single-factor screen is a weak test rather than proof, so same-source inflation is carried into the limitations rather than declared resolved.

Table 5. Discriminant validity: chi-square difference test with the correlation free and fixed to unity, and the heterotrait-monotrait ratio.
Source: Authors.

Construct pair	χ^2 free	χ^2 fixed	$\Delta\chi^2$	Δdf	p	HTMT	Dist inct
Urban form – Car reliance	254.5	903.0	648.5	1	< 0.001	0.557	Yes
Urban form – Daily life	254.5	1240.2	985.7	1	< 0.001	0.546	Yes
Urban form – Walking attitude	254.5	924.5	670.0	1	< 0.001	0.331	Yes
Car reliance – Daily life	254.5	675.3	420.7	1	< 0.001	0.699	Yes
Car reliance – Walking attitude	254.5	933.8	679.3	1	< 0.001	0.306	Yes
Daily life – Walking attitude	254.5	934.3	679.8	1	< 0.001	0.309	Yes

**Note: Differences are computed before rounding. HTMT is the heterotrait-monotrait ratio, read against the 0.85 mark.*

4.2. Structural model, mediation and prediction

Table 6 reports the structural model. Perceived urban form has a direct effect on car reliance of $\beta = -0.509$ (SE = 0.040, $p < 0.001$), supporting H1, and a direct effect on automobile-oriented life of $\beta = -0.211$ (SE = 0.052, $p < 0.001$), supporting H2. Car reliance has an effect on automobile-oriented life of $\beta = +0.559$ (SE = 0.049, $p < 0.001$), supporting H3. The model explains $R^2 = 0.321$ of the variance in car reliance and $R^2 = 0.528$ in automobile-oriented life, with effect sizes reported in the table. Figure 4 presents the estimated model. The structural layer is saturated, so the model's global fit is the measurement-model fit reported above, and Figure 4 labels it as such.

Table 6. Structural model: direct, indirect and total effects, and predictive assessment. *Source: Authors.*

Path or statistic	Estimate	SE	p	95% CI	Result
H1 Perceived form → Car reliance	-0.509	0.040	< 0.001	[-0.584, -0.429]	Supported
H2 Perceived form → Daily life	-0.211	0.052	< 0.001	[-0.312, -0.108]	Supported
H3 Car reliance → Daily life	+0.559	0.049	< 0.001	[+0.462, +0.654]	Supported
H4 Indirect effect through	-0.284	0.036	< 0.001	[-0.359, -0.218]	Complementary

Path or statistic	Estimate	SE	p	95% CI	Result
car reliance					
Total effect of perceived urban form	-0.495	0.042	< 0.001	[-0.575, -0.409]	57% indirect
R ² Car reliance	0.321			[0.244, 0.404]	Moderate
R ² Daily life	0.528			[0.451, 0.611]	Substantial
Effect size f ² : form → life	0.063			[0.017, 0.143]	Small
Effect size f ² : car reliance → daily life	0.449			[0.281, 0.698]	Large
Cross-validated RMSE, held out	0.637				0.633 in training

**Note: Daily life is automobile-oriented life. Standard errors, p values and intervals come from 5,000 stratified resamples of the whole procedure, every one of which converged.*

The indirect path from perceived form through car reliance to automobile-oriented life is $\beta = -0.284$, with a bootstrap percentile interval of $[-0.359, -0.218]$, and it accounts for 57 per cent of the total effect. Read against the direct effect, the pattern corresponds to complementary mediation, which is what H4 anticipated. Where the direct path is small and the indirect path carries most of the total effect, the practical implication is that changing the street changes daily life mainly by changing how much the car is needed, and interventions that reduce car necessity without touching the fabric would be expected to produce a comparable shift.

boxes with rounded corners are latent variables; small squares are the observed items that measure them

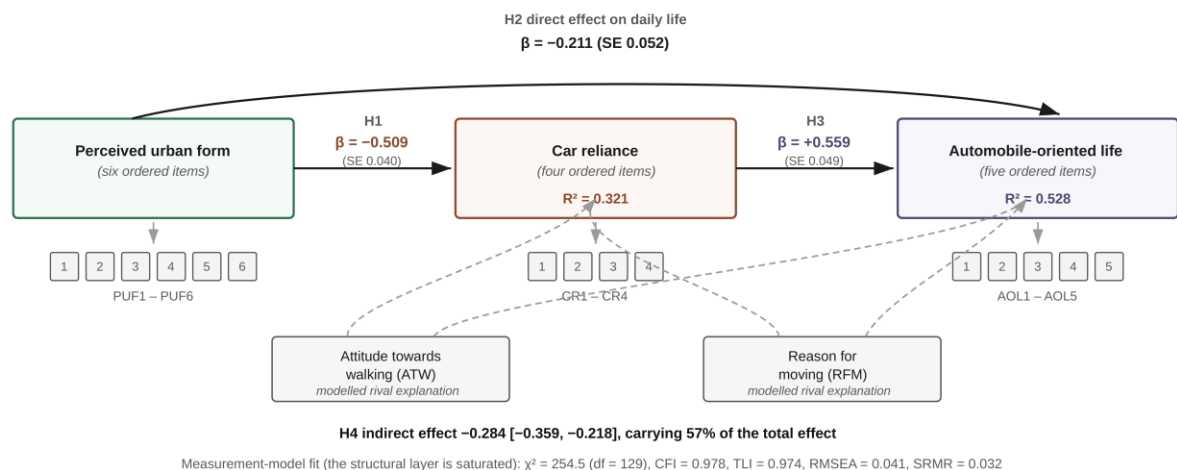


Figure 4. Estimated structural model. *Source: Authors.*

The fit indices carry weight here that they would not under an estimator reporting no global test, and they are read in the same spirit as the coefficients. A comparative fit index of 0.978 and a root mean square error of approximation of 0.041 sit inside the usual marks of 0.95 and 0.06, so the specified structure reproduces the observed associations

closely. Had they fallen the other way, the repair would not have been to add paths until the model passed; a model reshaped until it fits has stopped testing anything.

The rival explanations behave as rivals should. The walking attitude carries -0.082 to car reliance and -0.048 to daily life, the dwelling-reason indicator -0.147 and -0.085 , and with both included the form-to-car-reliance path is -0.491 against -0.509 and the indirect effect -0.267 against -0.284 , so the form coefficients do not move materially and the objection that residents of walkable quarters simply prefer walking does not carry the result. Because the car-share and car-free-day indicators share surface content with the car-reliance items, the structural solution was also repeated with both removed: the car-reliance path is then $+0.567$ and the indirect share 57 per cent, so the mediation does not rest on the overlapping items. Ten-fold cross-validation returned a root mean square error of 0.637 on held-out cases against 0.633 in training, in standard-deviation units of the outcome composite, and every one of the five thousand resamples converged.

4.3. Comparison across the three form generations

The generational comparison is where the paper's own claim is tested rather than borrowed. Figure 5 gives the activity-tether profile for each stratum: the mean number of daily activities reached on foot, the number requiring a car, and the number abandoned.

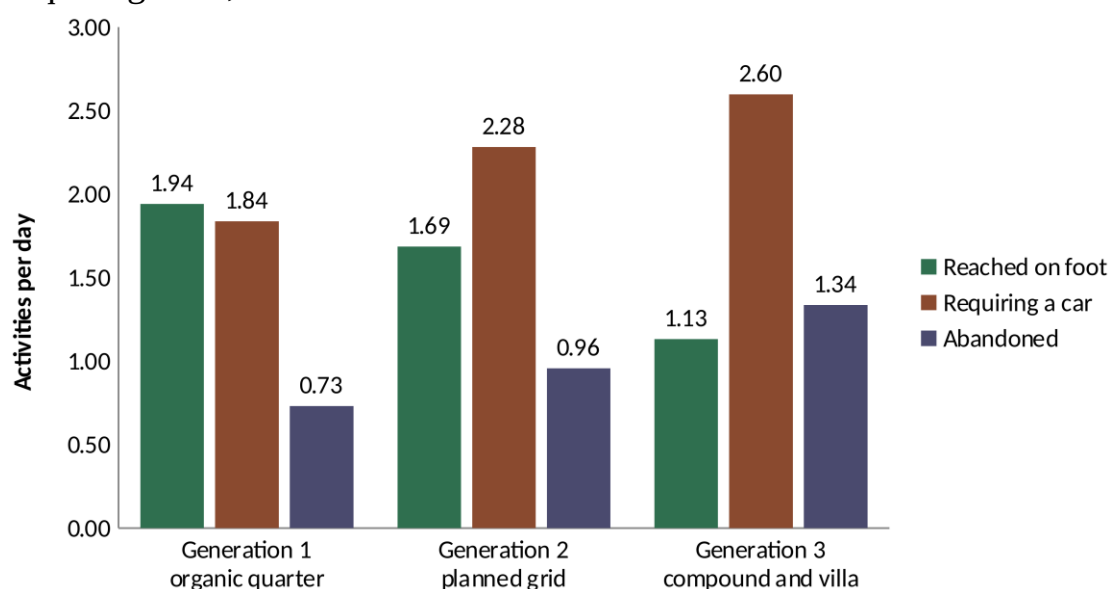


Figure 5. Activity-tether profile by form generation. *Source: Authors.*

Residents of the organic quarters reported 1.94 activities on foot against 1.13 in the compounds, while abandoned activities ran at 0.73 and 1.34 respectively; journeys by shared taxi or bus sat between 0.24 and 0.28



activities a day across the strata and count as neither walking nor car use. Children's independent activities average 0.99 a day in the organic quarters and 0.48 in the compounds. Measurement invariance across the three strata held at the metric level, judged on a change in the comparative fit index of -0.003 [65], so the paths can be compared. On the pooled loadings the car-reliance-to-life path runs 0.40, 0.55 and 0.71 across the three generations. The permutation test against a null built from 500 relabellings returned $p = 0.816$ on the form-to-car-reliance spread, $p = 0.436$ on the direct form-to-life spread, and $p = 0.040$ on the car-reliance-to-life spread; because the omnibus spread is blunt at two hundred respondents a stratum, the two ends were also compared directly, and the car-reliance path is 0.310 higher in the compounds than in the organic quarters ($p = 0.014$). H5 is therefore supported for the path that carries the argument, and for no other.

Two readings of that difference were available in advance: a fabric effect, or household resources dressed as morphology, since the strata differ in income and vehicle ownership as well as in form. The data choose the first. With household income and vehicle availability entered as covariates the car-reliance path still runs from 0.393 in the organic quarters to 0.760 in the compounds, so the fabric is doing work that household resources do not account for. The abandoned-activity count is the indicator that carries it, since it moves when a constraint binds rather than when a preference changes.

5. Discussion

The first question was whether perceived urban form predicts how far daily life has been reorganised around the car, and how much of that effect travels through car reliance. On the estimates in Table 6 the answer is that it does, and strongly: a standard deviation of perceived form moves automobile-oriented life by 0.495 of a standard deviation in total, with 57 per cent of the total effect carried indirectly. That share is uncomfortable for a certain kind of design optimism, because it means the street works on daily life at one remove: widening a footway lowers the cost of a walk that still has nowhere to go. The design was built so that this had an answer rather than a preference, and the answer came back large.

The second question was whether the pattern differs across fabrics built in different eras and lived in at the same time. That comparison could not have been made anywhere with a single urban form, and it also carries the most risk, since three strata inside one municipality differ in income and household composition as well as in morphology. What survives the controls is the difference that matters: the car-reliance-to-daily-life path

still runs from 0.393 to 0.760 with income and vehicle availability held, while the form-to-car-reliance path is statistically indistinguishable across the fabrics. The generations differ not in how form produces car reliance but in what car reliance then does to the day, and a form effect that vanished under an income control would have been an income story all along; this one did not vanish.

The third question is the one a planning office asks first. If the lever is the street, the instruments are continuity, shade, crossings and the return of small retail to residential fabric, and they work slowly. If the lever is the traffic, the instruments are parking, arterial speed, where the next mall goes and whether the next compound may seal its edge, and they work faster and cost less. With 57 per cent of the effect running through car reliance, the second set carries more of the change available, which is why car reliance was modelled as a path rather than an outcome. Erbil still has both levers: the walkable fabric has not been demolished, and the ring-road landscape is young enough that the next decade of building is not yet fixed.

A broader point follows, and it is worth stating carefully. Dispersal in Erbil is unlikely to have reduced raw access: the road network puts more of the city within an hour of a compound than the old quarters could ever offer, though this survey measures no travel times. What the survey does show changing is who holds that access and on what condition. The tether lengthened and stiffened at once. That is a reallocation rather than a loss, and it falls along the lines documented earlier [49–51]. Children are the clearest case. A child in the organic quarters reaches school, a friend and a shop without an adult; a child in a walled compound reaches the compound. The difference between 0.99 and 0.48 independent activities a day is a fact about childhood, not only about transport.

There is a theoretical point the design was built to make. Car dependence has been treated as a property of places and, more recently, as a property of systems of provision [6]. Both readings are right and neither sits at the scale where residents meet the problem, which is a week that has quietly reorganised itself so that nothing in it works without a vehicle. Naming that as a construct, giving it indicators that can be counted and putting it at the end of a model is a modest addition, but it is what lets the question be asked empirically. The abandoned activity deserves wider use: it measures the constraint where it has already won, and a survey asking only how people travelled will never see it.

For policy the implication is not compactness in the abstract, which does not deliver on its own [29,31], but something narrower. Permit conditions can be written around network connection rather than density, since a



compound that joins the surrounding fabric at more than one point behaves differently from one that does not. The small retail the old quarters carry inside the residential fabric is the feature most associated with activities reached on foot, and current practice consolidates it into malls at junctions. Shade here is infrastructure rather than amenity. And the sequence matters: reducing the need to travel is cheaper than improving the speed of travel, and it is what changes the shape of a day [52].

Several limitations bound all of this. The design is cross-sectional, so the model estimates association with a specified direction rather than change observed over time; the causal reading rests on the mechanism being stated and on self-selection being modelled [24,25]. The recall asks a respondent to reconstruct one day, and abandoned activity is the item most vulnerable to under-reporting, since a journey never attempted may not be remembered as forgone. Perceived form is used deliberately, but it is not an audit, and pairing the instrument with one would let the divergence itself be studied. The single-city design buys control at the cost of external validity, and the June fieldwork makes the shade and comfort readings hottest-season perceptions. All items share one informant and one sitting, so some same-source inflation survives the procedural separations, and the wording overlap between the car-reliance items and two outcome indicators, though the robustness check bounds it, is a risk a second instrument should remove. Finally, car reliance is treated as a single mediator when the system producing it includes provision, land allocation and industry [6], which a household-level model cannot see.

6. Conclusions

The contribution can be put in a sentence. By placing car use in the middle of the model rather than at the end, and by measuring the reorganisation of ordinary life directly instead of inferring it from trip counts, this study shows that 57 per cent of the effect of urban form on daily life travels through the car and the remaining 43 per cent does not, in a city where the walkable alternative is a working neighbourhood a few kilometres from the ring road.

What would settle the questions this design cannot? Two things. A panel following households across a move between form generations would convert association into observed change and deal with self-selection more convincingly than any cross-sectional control [22]. And a repeated cross-section in a city still building would show whether the

reorganisation continues after motorisation levels off, which decides whether Erbil is following its neighbours' path or one of its own [9]. The tether is longer than it has ever been. The question for the next decade of building is who holds the other end of it.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study. The questionnaire opened with a consent question that every respondent answered before any other item was put, and no identifying information was recorded.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

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