Chapter 2:

Review: Density Measures and Research

Introduction and Definitions

All the density measures discussed here are ratios. The numerator may be the number of persons, families, households, habitable rooms, bedrooms, housing units or dwelling units (DUs).

Where one numerator unit is inferred from another, rather than being the direct unit of measurement, there is an explicit or implicit conversion factor. For example, the conversion of density measured in persons per acre to households per acre requires an assumption about average household or family size.

Similarly, to convert densities measured in population units (persons, families or households) to measurements using housing units (bedrooms or habitable rooms, DUs) assumptions about occupancy rates have to be made: the number of habitable rooms per household, or whether each household occupies one DU. Some of these assumptions may be robust in terms of reflecting the actual social and demographic characteristics of the relevant population. For example, for suburban U.S. communities one household usually does occupy one DU. Other assumptions may be less robust, and the resulting measurements may be correspondingly less accurate.

The denominator in all these density measure ratios is a unit of area. The unit of area may vary in two respects. One is the unit of measurement (acres, hectares, or square miles) and the other is the definition of the boundary. The unit of measurement does not raise any problem. Any unit of measurement can be transformed into any other by simple arithmetical conversion, though the extension in space of an "acre", a "hectare" or a "square mile" is not easily intuitively comprehended.

The definition of the boundary, on the other hand, has been the source of a great deal of ambiguity and fuzziness in much previous work on densities, as the review below will show. To avoid this a set of terms that will be used in this study, and their exact definitions, are presented below. These terms, or standard measures, will serve as points of reference for the review that follows.

Net Dwelling Density (NDD)
The numerator for the Net Dwelling Density (NDD) may be any of the units suggested above, ranging from persons to DUs. The denominator is the "net residential site area", defined as the "total land area devoted to residential facilities".

In single or two-family housing areas this will normally be the area of the dwelling lots, and can include driveways, front, back and side yards, private gardens, and ancilliary structures like garages, toolsheds, etc. In higher density developments the net residential site area includes private access drives and parking areas related to the dwellings, play spaces, gardens and adjacent landscaped areas directly related to the residential use. Excluded from this area are commercial and industrial areas, shopping and local business not directly beneath residential buildings, commercial garage space not directly below a dwelling structure, public parks and playgrounds, vacant land for future development, vacant unbuildable land, schools, churches and community facilities, institutions, and public streets and parking spaces (APHA, 1960: 73).

Gross Residential Density (GRD)
The Gross Residential Density (GRD) is the ratio of any of the above numerator units (persons, households, DUs) to the "gross residential site area". The gross residential site area is the net residential site area + half the area of the perimeter roads, + one quarter of the area of the intersections. If perimeter roads are over 100' wide, the gross residential area includes only up to 50' from the property line (APHA, 1960: 37, 74).

Neighborhood Density (ND)
Neighborhood Density is the number of persons, households, or DUs per acre, hectare, or square mile of total neighborhood land. Neighborhood land includes residential land, streets, and other landuses for neighborhood community purposes such as schools, recreation, religion, culture, and neighborhood retail shopping. Non- neighborhood landuses such as public and semipublic services, citywide business and commercial establishments, secondary and higher education, industry, major arterials and freeways, city, metropolitan or regional parks or recreation facilties, and vacant or unusable land are excluded (APHA, 1960: 63).

City Density (CD)
City density is the ratio of persons, households, rooms, or DUs to the entire area of the city, regardless of land use. This is the same as the British "town density" (James, 1967: 55). The numerators

DENSITY MEASURES

NUMERATOR UNITS	NDD Net Dwelling Density	GRD Gross Residential Density	ND Neighborhood Density	CD City Density
Persons		APHA(1960) gross res. density Gibberd(1967) nett neigh. density James (1967) net density (20' roads) Jensen(1966) net density Stevens(1960) housing area density	Gibberd(1967) gross neigh. density Keeble(1969) gross pop. density James(1967) gross density Jensen (1966) gross density	APHA(1960) district density Camerom (1980) James (1967) town density Jensen(1966) town density
Households		APHA(1960)		APHA(1960) district density
Rooms			Corvallis (League of Oregon Cities 1977)	
Dwelling Units	*APHA (1960) *FHA (1971) net density Keeble (1966) nett res.density Martin and March (1972) Hoffman(1967)	APHA(1960) gross dwelling density (50' roads) Cameron(1980) net housing density FHA(1971) gross density Martin and March (1972) Gibberd(1967) net neighborhood density	APHA (1960) net density Gibberd (1967) gross neighbor-hood density	APHA (1960) district density Keeble (1969)

Table 2-1: Comparative Density Measures.

most commonly used for this measure are persons or households. A remaining source of ambiguity is the delimitation of the land area included: it can be defined by a city's jurisdictional boundaries and then would include all vacant and undeveloped land within the city limits; or it can be limited to the urbanized or contiguous built-up area of the city. Since this study will not dwell much on city densities, this ambiguity is left unresolved.

Density Measures: A Review

Using the measures and definitions presented above as points of reference, we can explore the array of preceding density measures that have been developed and applied. These measures, for the most part, are remarkable for combining diverse names with relatively convergent definitions. At the same time, one has the impression of many authors, through the 1960s and 70s, each "reinventing the wheel" with little or no reference to their predecessors.

In Table 2-1, 28 density measures from 11 sources are arrayed by their relative correspondence to the "benchmark" measures we have defined above. Another four sources use density measures that are so vague and indeterminate that they cannot even be placed on this chart.

Five measures correspond or closely approximate to our NDD. The identical ones are the "net residential densities" of the APHA (1960), Hoffman (1967), Martin and March (1969), and Keeble (1971). The FHA's "net density" is more ambiguous about the street and parking areas that are included (FHA, 1965:8).

Nine measures are clustered around our GRD. Of these, five are identical. They include the APHA's "gross dwelling unit density" (1960), other "gross densities" (Martin and March 1969; FHA, 1971), Stevens' "housing area density" (1960), and Cameron's "net housing density" (1980). James' (1967) "net density" is very similar, the only difference being that he only includes up to 20' of peripheral roads. The APHA's (1960) "gross residential density", Jensen's (1966) "net density" and Gibberd's (1967) "net neighborhood density" veer towards our Neighborhood Density in being more inclusive in the range of landuses defined as belonging to a neighborhood rather than the city as a whole.

Seven measures roughly correspond to our Neighborhood Density. Identical are the APHA's (1960) neighborhood density, Gibberd's (1967) "gross neighborhood density" (using either persons or DUs in the numerator), and James' (1967) and Corvallis' (League of Oregon Cities, 1977) gross densities. Jensen's (1966) and Keeble's (1971) density measures include in their denominators some landuses that our definition allocates to cities.

The APHA's (1960) "District Density" is nearly equivalent to our City Density. Four other measures (Jensen, 1966; James, 1967; Keeble, 1971; Cameron, 1980) are identical to the CD used here. This array suggests that the wide variety of terms used by different sources for the same measurement conceals a significant degree of convergence.

The density measures arrayed in Table 2-1 are the ones that are fairly well defined. Frequently in the literature there are references to density which are so indeterminate that they could not be placed anywhere on this chart with any confidence. Besides the many such references, several authors of studies relating to density have also used density measures with so little precision that they cannot be related to any one or other of the measures we have defined here. They include Crothers'(1976) "gross density", Diamond's (1976) use of DUs/acre (without specifying acres of what), Flachsbart's (1979) "residential density", and Windsor's (1979) "gross- and nett unit density".

Studies of Density and Urban Form

Considering the widespread applications of density measures in regulation, planning, and urban design, the relative lack of research into density measures is surprising. Even more surprising is the lack of convergence in this area of study. To avoid these errors we have reviewed all the previously developed density measures and applications we could find, and compared them to our measures as defined above. This review continues with a presentation of precedent research related to density measures and urban form.

This research can be grouped into several unequal categories:

* 1).Studies of density related to human perceptions and behavior: A considerable volume of work exists which relates density to perceptions of crowding, privacy, territoriality, and related behavior. An example is Gillis and Hagan's (1979) study relating density and delinquency. This body of research will not be reviewed here (a good review is provided by Krupat, 1985: 99-113, 176-184) because it is not central to our concerns. It is relevant, of course, to the ultimate concept this study is addressing: that of perceived density. But in relation to our immediate focus on measured densities, this work is peripheral. We consider this exclusion reasonable, since density in this sense is often used more as a broad

concept or indicator, without the precision implied by density as a measure of an observed or experienced phenomenon.

* 2).Density and land economics: Several studies relate density (with more or less exact measures) to economic variables such as housing prices and development costs. Urban form impacts are sometimes derived, including the shapes of buildings near the CBD and the costs and benefits of low-density suburban development.
* 3).Planning Prescriptions and Descriptions: Planning prescriptions for optimum densities are frequent. These studies sometimes arise out of description and analysis of historical and cultural prototypes, but often they are directly normative prescriptions where specific density ranges are associated with particular dwelling types.
* 4).Density measures -- applications and problems: A relatively sparse body of research presents examples of density measure applications and analyzes some of their related problems. Some of this work has already been referred to above, and it is highly relevant to our concerns.
* 5).Density and urban form: Several studies have shown a concern paralleling ours with the relation between density measures and urban form. Some resemble this one in their methodology, though none combine the deductive and inductive modes applied here. These studies are reviewed in detail below.

Density, Perceptions and Behavior

Representing the extensive body of research relating density,perception, and behavior, two specific studies can serve as examples. Lerup (1971) investigated the relationship between open space, access, and dwelling types and their densities. He concludes that courtyard type buildings use land more efficiently than pavillion type structures (cf. Martin and March, 1966, 1972). His concept of "intensity of activity" related to density is interesting and potentially useful, but the interaction between the two remains vague and underspecified.

Yeung (1977) is one of a long line of researchers basing their conclusions on the high rise housing experience of Hong Kong (see for example Mitchell, 1971). Distinguishing between internal density measures (occupancy) and external density measures (persons per unit area of land), he suggests that prevailing norms (e.g the U.N's suggestion of an average density of one person per room for privacy, with three or more persons suggesting undesirable crowding) are untenable. Yeung refutes two "myths" about high rise housing: it is not significantly more efficient, in terms of producing higher external densities, nor does it necessarily result in less living space, i.e. higher internal densities.

Density and Land Economics

Several studies have explored the implications of low density suburban type development in terms of its economic efficiency. *The Costs of Sprawl* (RERC, 1974) suggested that this type of development was inefficient, and that substantial savings could result from the adoption of higher density cluster- type housing. This analysis used two scales of development, the first comparing five alternative housing types in standard developments of 1000 DUs each, the second showing five alternative mixed development patterns in communities of 10,000 DUs on a standard 6000 acre site. The density measures here (as in the succeeding studies) are incidental, and result from the housing units and site arrangements displayed. Density, then, (as is so often the case) is used almost anecdotally, and related to specific dwelling types and patterns of development.

Indeed, the loose use of density measures is one of the aspects of Windsor's (1979) critique of "The Costs of Sprawl". Exposing the previous study's assumptions, Windsor recomputes the occupancy (floor area per resident), net unit density (= our NDD), and gross unit density (= our GRD) for each of the alternative developments. He finds that while size and demographic composition of the population is held constant in the community prototypes, they are varied in the neighborhood prototypes, and that the floor areas of DUs change, with smaller units at higher densities. All these variations affect costs, so that density effects are inextricably confused with variations due to other factors. The reanalysis of RERC's data suggests different conclusions: private capital costs appear to be lowest for medium density development such as townhouses or low-rise apartments. Environmental impacts and population-dependent public costs seem to be lowest using planned single-family development as a form of growth management.

Resembling "The Costs of Sprawl" in its aims is Ottensmann's (1977) study which "proves" what is acknowledged as a truism: that denser development takes place on more expensive land. Density, however, is represented here by a surrogate measure: population, to which it is, in fact, only weakly related. Buttler (1981) comes to a similar conclusion, but his method is more sophisticated and incorporates several density attributes: population density, DUs per building, and FAR. His analysis finds that a competitive housing market in equilibrium will elicit narrow and tall buildings close to the CBD, and that building heights and minimum areas tend to be determined by technology and codes.

Sanders' "Zero Lot Lines can Trim Costs" (1982) also makes a case for the greater economic efficencies for the higher net densities attainable through zero lot line zoning. Inadequately considered are the implications of the relation between NDD, GRD and ND, the latter two affecting development costs more than the former, but being much more marginally affected by changes in development patterns (cf., for example, Alexander 1968).

Planning - Descriptions and Prescriptions
55 years ago normative regulations involving density were already the subject of discussion and debate. Lanchester (1934) proposed a formula that would reward low density development by requiring a lower proportion of open space (including roads), and suggested a variation of conventional density measures to assess density at cubic feet of volume per acre. His proposals were accompanied (as was often the case later) by descriptions of prevailing densities and regulations elsewhere.

The set of subsequent proponents of density standards associated with specific dwelling types includes Segal (1964), Gibberd (1967) and de Chiara and Koppelman, whose *Urban Planning and Design Criteria* (4th. Edition, 1982) is probably the most widely used U.S. reference of its kind today. Reflecting current third world attitudes, Okpala (1978) reviews density patterns in Nigeria, and suggests a revision of prevailing regulations based on western norms to allow the higher densities more typical of his country's lifestyles.

Unlike Okpala's proposals, however, most normative work on residential densities does not rest on any descriptive or analytical base, or at least none is cited. We have to assume, then, that it reflects some kind of intuitive knowledge based on a body of experience. One exception is Keeble (1969, 1971) who proceeds from a set of precise definitions of density measures (see Fig.1 and following above) and analyzes the different density impacts of various combinations of dwelling types. Another is the FHA's (1971) development of its "Land Use Intensity (LUI) Scale", which was stimulated by a proper disenchantment with simplistic density measures, and is based on a complex set of indexes reflecting various dimensions of land use intensity.

Lever (1971) refers to "Positive Standards" (i.e density measures in practice) in his presentation of "Normative Standards". He correctly notes the lack of planning control over occupancy; thus building density measures (DUs/acre or Habitable rooms/acre) are the only ones that are usable in planning and regulation. Sussna's (1973) study is primarily descriptive, presenting densities in some new planned communities in the U.S. and comparing population and density standards for ideal communities.

Applications and Problems

Applications of density measures in planning and regulation are described in Keeble (1971) and Lever (1971). A League of Oregon Cities (1977) study reviews practices in several municipalities, and includes substantial references to FHA standards. Cameron (1980) describes applications of density measures, focusing on practice in developing countries.

An early but useful review of norms and practice (Stevens, 1960) shows how other regulatory and environmental criteria e.g health standards and infrastructure capacities and requirements, may be affected by changes in density. Though our study that follows will not include these factors, they are worth bearing in mind.

Several studies address conceptual or practical problems involving density measures. Crothers (1976) raises the question of defining the area concerned, and how this raises problems of indeterminacy of density measures. The way such an area is bounded may affect its self-containment, in terms of the array of interdependent landuses that are included. This can certainly be a real issue in determining higher level densities -- ND or CD -- but for lower level density measures -- NDD and GRD -- it can safely be ignored.

Keeble's (1971) study critiques conventional density measures for their rigidity and aggregation (cf. Stein, 1978, below) and their imprecision (referring e.g. to the differences between the English, Scottish and Irish acre). He proposes to substitute performance standards involving space-height relationships, design quality, and parking provision for conventional density controls.

Stein (1978) discusses the weaknesses of several measures. "Accommodation density", or the number of habitable rooms/acre, is problematic because the number of persons per room is not taken into account, and the definition of "habitable" rooms is vague. Similar problems plague the habitable floor space/acre index. Population density fails to reflect concentrations of people (as in high-rise structures) but divided by accommodation density it can produce an occupancy rate (persons per habitable room). Stein notes that a common characteristic of all density measures is their inflexibility, both in reflecting spatial differences (concentration or dispersion) and temporal ones (e.g differences between daytime and nightime use). One cannot but agree, but then again, this characteristic of all aggregated measures is inseparable from their usefulness and generalizability. Instead of rigid density standards, Stein (like Keeble, above) advocates performance zoning, suggesting a combination of population policies and "proxemics"-based criteria. This idea may warrant further development, but it might be of doubtful feasibility.

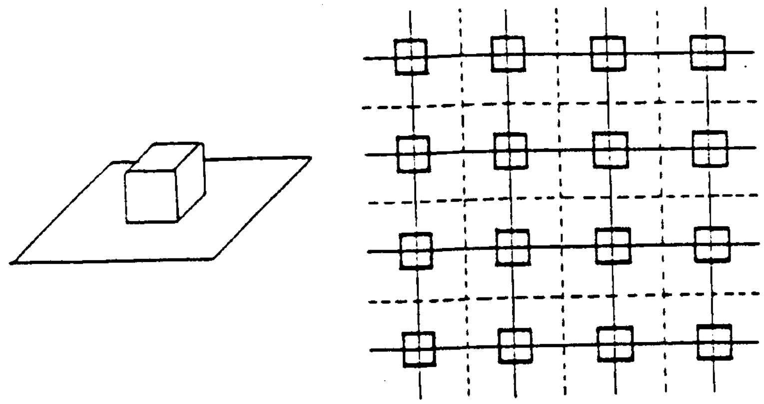
An interesting study by Flachsbart (1979) exposes the limitations of density measures in reflecting perceived densities. In relating observers' estimation of densities in several California cities to the measured densities he found a systematic tendency to underestimate physical densities, which is related to the frequency of streets and to block sizes. Flachsbart infers that areas with shorter blocks and more street intersections will seem to have lower densities than their actual objective densities, and thus will be perceived as more satisfying environments. His study is flawed, however, by lack of definition of density and a confusion between NDD, GRD, and ND. Consequently the "objective density" of the neighborhood layout he advocates may in fact be lower (in terms of GRD and ND) than that of an area with fewer streets (both areas sharing the same NDD); this makes the lower perceived density unsurprising.

Density and Urban Form

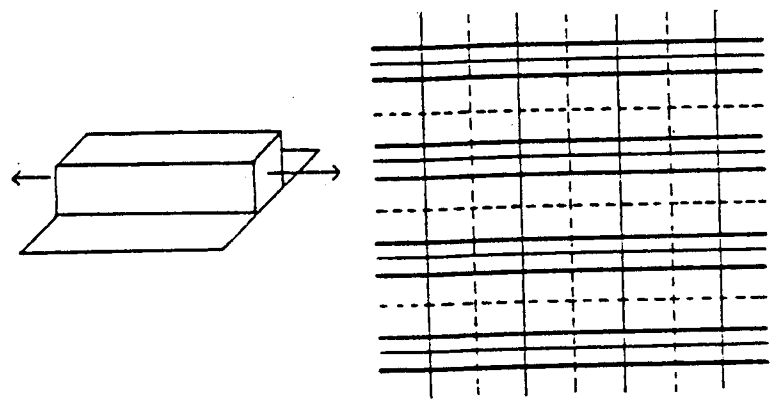
In the early 1960s Sir Leslie Martin and Lionel March were the first, in a series of studies at the Institute for Land Use and Built Form Studies, Cambridge University, to explore some of the relations between density and built environments. The impact of several alternative forms of structure and layout -- pavilion or tower, street, and court -- on various attributes of the environments created (coverage and FAR, called respectively the "site utilization factor" and "the built potential") was systematically analyzed (Figure 2-1). These types of structures were developed in prismatic (e.g. pyramidal), orthogonal, and combined forms, including some interesting "figure- ground" type contrasts and juxtapositions.

The conclusions were that court building forms were more efficient than pavillion or tower types in enabling higher density development while preserving site amenities (light penetration, open space, etc.), suggesting a reversal of conventional economic wisdom. They also found that the size of site, and the street systems are critical variables, suggesting that planning consideration be devoted to "loosening up" city texture so as to allow more effective development patterns (Martin and March, 1966;, 1972: 6-36).

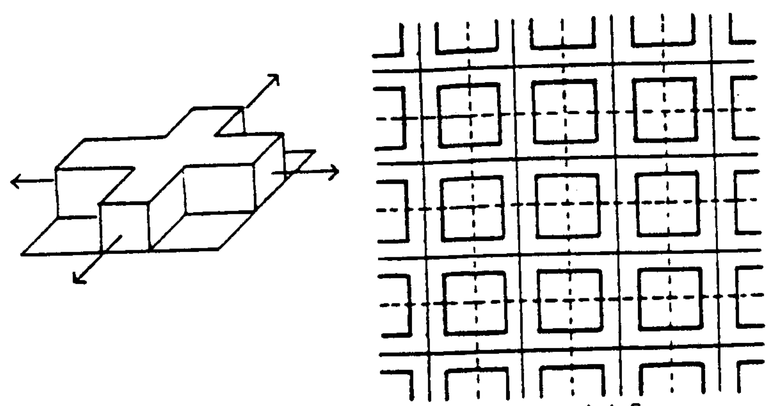
Martin and March's studies are a prototype for the deductive methodology used later (e.g. by Keeble, 1969 and Diamond, 1976,



2.0 Pavilion form extended. S.



2.1 Street form extended. S.



2.2 Court form extended. S.

Fig.2-1: Density & Built Form Analysis(Martin & March, 1972)

see below) and here. The relationships between density indicators and built forms are not taken for granted, nor are prevailing truisms accepted - for example, that high-rise towers enable higher densities and thus reduce development costs. Instead, these relationships are explored through systematic variation of building form.

A similarly deductive approach is adopted in the London County Council's analysis of theoretical new town plans, which systematically varies net densities and housing mixes while holding other variables constant (London County Council, 1961). This study exposes the "dampening" effects of GRD and ND on CD, so that even when the residential area increases in size dramatically as NDDs are reduced, the effect on the radius of a circular town is small. In contrast to Martin and March's, Diamond's, and our work, which is mainly at the microscale of the site and block, this study shows the feasible extension of this approach to the macroscale of the town or city. It suggests that there is a critical CD which

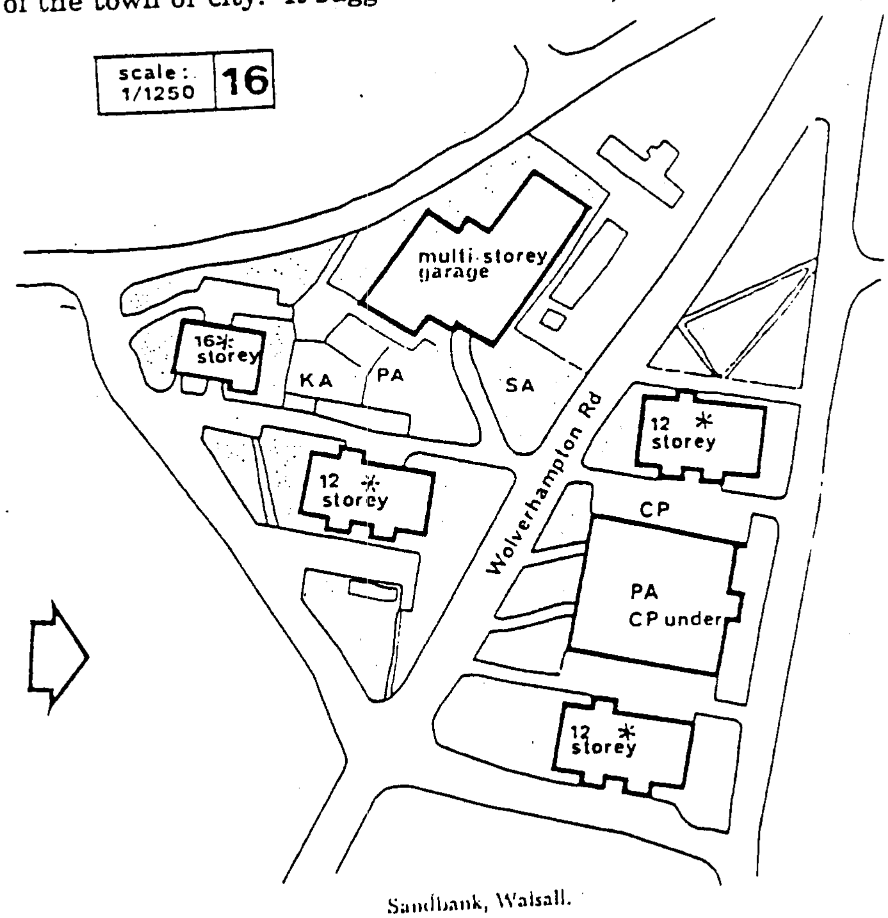
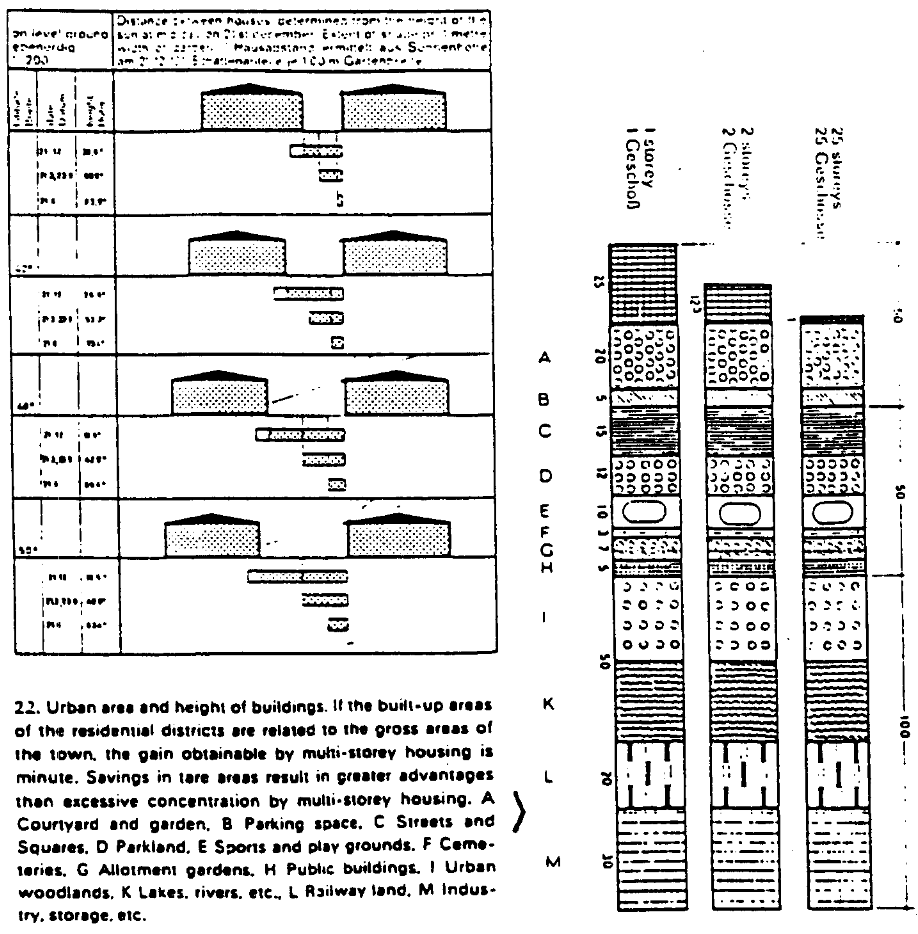


Figure 2-2: Neighborhood Density Analysis (James (1967).

can support local services without demanding unduly long trips. While this CD is compatible with a whole range of possible NDDs and alternative mixes of dwelling types, the study suggests that higher densities increase accessibility and choice.

James (1967) is also an important forerunner, especially in his precise definition of a range of density measures which closely parallel our own (though the names differ; see above). His analysis at the meso-scale (bridging Martin and March's work, which he cites, and the LCC's study) reviews the purported advantages of higher density residential development through an analysis of actual neighborhood layouts (Figure 2-2). His conclusions closely parallel his predecessors': he doubts the value of extremely high densities of around 70-80 persons per acre (ppa) and recommends more moderate gross densities (=ND) of 30-50 ppa which correspond to net densities (=GRD) of 30-50 ppa. He refers to other problems associated with high densities: design difficulties, and unresponsiveness to personal preferences for



2.2. Urban area and height of buildings. If the built-up areas of the residential districts are related to the gross areas of the town, the gain obtainable by multi-storey housing is minute. Savings in tare areas result in greater advantages than excessive concentration by multi-storey housing. A Courtyard and garden, B Parking space, C Streets and Squares, D Parkland, E Sports and play grounds, F Cemeteries, G Allotment gardens, H Public buildings, I Urban woodlands, K Lakes, rivers, etc., L Railway land, M Industry, storage, etc.

Fig.2-3: Housing Type & Density Relationships (Hoffman,1967) private outdoor space.

In its combination of deductive and inductive-descriptive approaches our work closely parallels Hoffman's (1967) review of row and cluster housing. His descriptive analysis shows how density affects sunlight penetration, and arrives at appropriate housing typologies for different climates and geographic locations (Figure 2-3). His computations show the relationships between floor space index (FSI), cubic content of dwelling types, population densities, and building densities (which, however, are poorly defined).

Keeble (1969) analyzes the NRDs of neighborhoods made up of varying dwelling types and configurations. He shows how densities are a function of plot dimensions (given specific dwelling types) and how densities are associated with dwelling types, their heights and spacing (Figure 2-4). Keeble computes densities for a variety of mixed housing developments, going up to the scale of

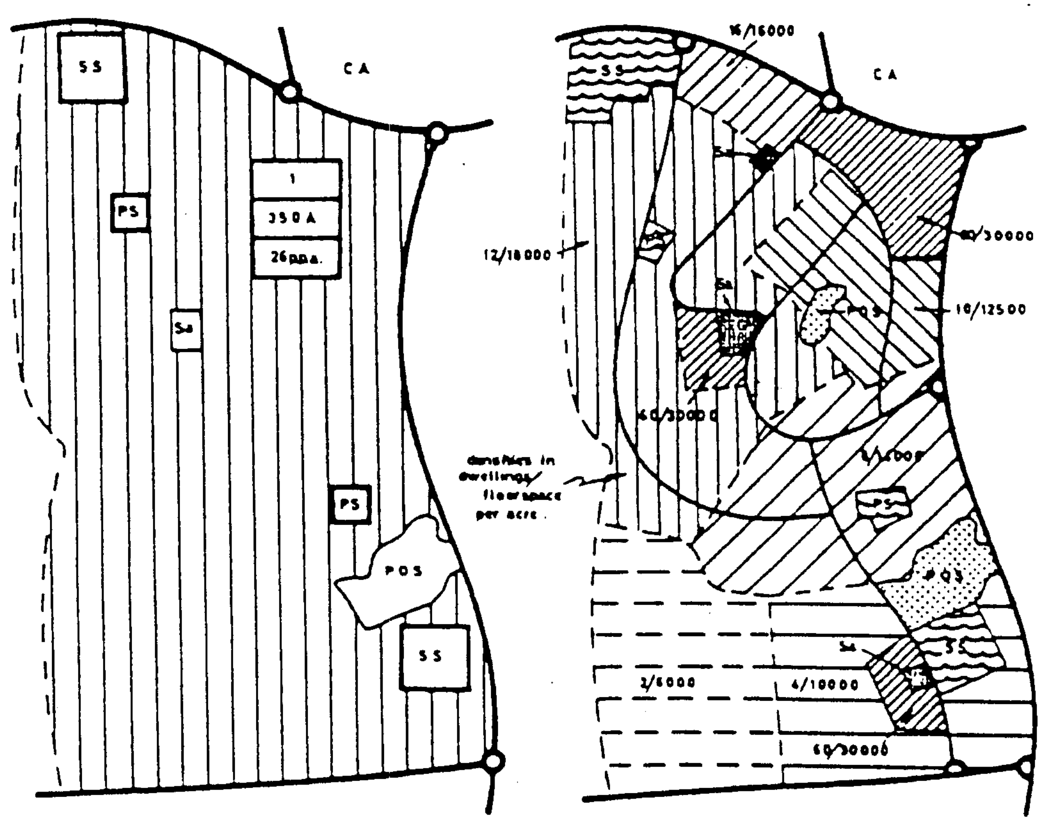


Figure 2-4: Density Analysis of Neighborhood (Keeble 1971)

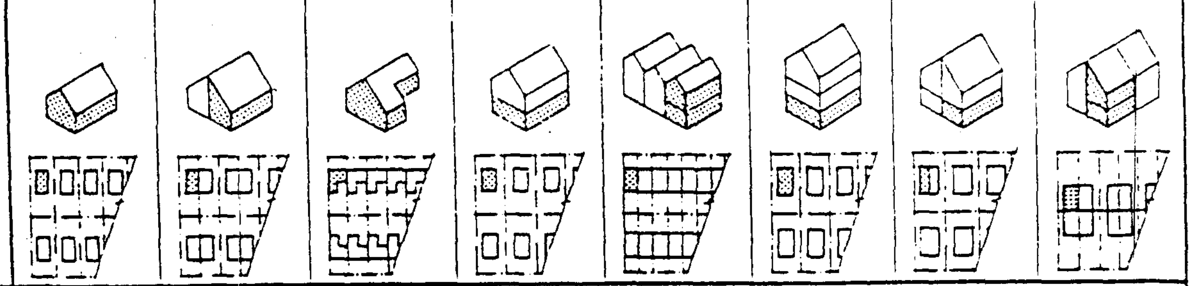
a complete New Town. He confirms previous researchers' conclusions that the effect of increased NDDs on overall CD is negligible (p.267), and explores the interactions between density, cost and appearance. Both in this text and in his later (1971) study Keeble also combines the deductive and inductive approaches, illustrating his propositions with typical neighborhood layouts. Many of Keeble's conclusions are somewhat subjective, though well supported by his analysis, and his evaluations surmount the test of time; for example:

> "The LCC's Roehampton Housing Estate.. The net residential density is said to be 80 ppa. It is generally recognised to be visually a triumph...It is difficult to avoid the conclusion that, even at the cost of some loss of visual excellence...it would have been better to provide a considerably larger proportion of houses and to give them substantially larger plots." (p.281)

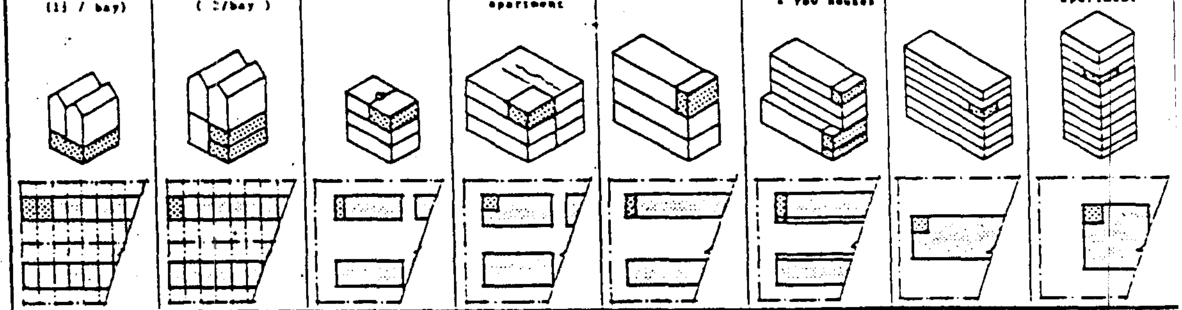
The deductive methodology of Diamond's (1976) analysis is also close to our own. He applies this analysis to make a case for middle level densities in residential development, as opposed to the conventional alternatives of high rise construction or low density single family housing. A graph of land required for a notional development of 3.0 persons per 1000 sq.ft. DU shows the required area increasing asymptotically as FARs go down. Associating specific FARs with dwelling types (single family = 0.25, row housing = 0.50, low-rise walkup apartments = 1.5) Diamond uses this to demonstrate the relative efficiency of mid-rise housing at intermediate densities. This argument is supported by a schematic diagram (Figure 2-5) showing a range of dwelling types and their associated layouts and density measures.

Diamond's analysis is somewhat simplistic, associating one FAR with each dwelling type. This implies not only the constant occupancy rate and dwelling size that Diamond assumes, but fixed densities as well. For example, the FAR of 0.25 he gives for single family housing generates a land requirement of 32 acres, presumably at a density of 8 DUs/acre (per his Fig.6). A FAR of 1.0 (mid- rise development of stacked row houses or garden apartments) for the same 256 DUs requires 8 acres only, i.e the average density is now 32 DUs/acre.

We know, however, that the association between dwelling types and densities is more complex. At the most elementary level, clearly single family detached housing can range in density from 0.2 DUs/acre (exurban large-lot development) to over 10 DUs/acre. These ranges of possible densities for different dwelling types will be one of the topics of our analysis later.



Dwelling Type	1 Single detached	2 Semi detached	3 Joined court	4 Duplex	5 Row house	6 Triplex	7 Quadruplex	8 Back to back Semi detached
Isometric								
Plot Plan								
Dwelling units/acre (dwelling units/hectare)	8 (20)	14 (35)	16 (40)	17 (42)	19 (47)	21 (52)	23 (57)	24 (59)
Floor area ratio % open space	0.24 76%	0.38 81%	0.44 56%	0.48 88%	0.55 72%	0.60 80%	0.66 67%	0.64 67%
Unit relationship to grade	on grade	on grade	on grade	50% on grade 50% gr. related	on grade	33% on grade 66% gr.unrelated	50% on grade 50% gr. related	on grade
Access to unit	private on grade	private on grade	private on grade	50% priv. on gr. 50% priv. stair	private on grade	33% priv. on gr. 66% common stair	50% priv. on gr. 50% priv. stair	private on grade
Unit aspect	quadruple	triple	triple	quadruple	double (opposite)	quadruple	triple	double (adjacent)
Private outdoor space	on grade	on grade	on grade	50% on grade 50% gr. related	on grade	33% on grade 66% gr.unrelated	50% on grade 50% gr. related	on grade
Parking	private on grade	private on grade	private on grade	common on grade	private or com. on grade or u/g	common on grade	common on grade	private on grade



Dwelling Type	9 Stacked row house (1½ / bay)	10 Stacked row house (2/bay)	11 Garden apartment	12 3 - storey walkup apartment	13 Medium rise stacked units	14 Combined apartments & row houses	15 Slab block apartment	16 High rise point block apartment
Isometric								
Plot Plan								
Dwelling units/acre (dwelling units/hectare)	31 (77)	35 (86)	52 (128)	65 (160)	71 (175)	84 (207)	90 (222)	120 (296)
Floor area ratio % open space	0.86 72%	1.14 72%	1.06 62%	1.36 55%	1.93 68%	1.92 62%	1.78 82%	2.62 87%
Unit relationship to grade	33% on grade 66% gr. related	50% on grade 50% gr.unrelated	33% on grade 66% gr.unrelated	33% on grade 66% gr.unrelated	33% on grade 33% gr. related 33% gr.unrelated	25% on grade 75% gr.unrelated	small % on grade majority ground unrelated	small % on grade majority ground unrelated
Access to unit	33% priv. at gr. 66% priv. stair	50% priv. at gr. 50% com. stair	common stair	common stair	common elevator	25% priv. at gr. 75% com. elev.	common elevator	common elevator
Unit aspect	double (opposite)	double (opposite)	double (opposite)	single	double (opposite)	double (opposite)	single (and double adj.)	single (and double adj.)
Private Outdoor space	33% on grade 66% gr. related	50% on grade 50% gr.unrelated	33% on grade 66% gr.unrelated	33% on grade 66% gr.unrelated	33% on grade 33% gr. related 33% gr.unrelated	25% on grade 75% gr.unrelated	small % on grade majority ground unrelated	small % on grade majority ground unrelated
Parking	common underground	common underground	common underground	common underground	common underground	common underground	common on grade or u/g	common on grade or u/g

Figure 2-5: Deductive Density Schema (Diamond, 1976)

The schema Diamond develops is sometimes richer than his graph suggests, showing variations within dwelling types that can result from different prototypes; e.g stacked row houses at 31 and 35 DUs/acre, depending on the plan arrangements and number of storeys. For many dwelling types, however, this schema shows only one (perhaps "typical"?) density, or a narrow range, e.g row house, "slab" and "point" block high rise apartments. A more complete analysis, such as the one developed here later, will include the effects on density of other variables, such as lot sizes and proportions (cf.Keeble, above), and block layouts.

Summary and Conclusions:

The preceding research on density measures that is reviewed above reveals a strange paradox. The normative use of density measures continues, and several of the studies are devoted to the development of planning and design prescriptions. At the same time, many of the analyses expose problems with density measures and their applications. These problems include indeterminacy and ambiguity, oversimplification and overaggregation, and possibly a weak relationship with perceived density, which, after all, is what measured densities are ultimately about.

In response some attempts have been made to develop indexes of land use intensity that are richer and more discriminating than conventional density measures, used singly or in combination. These indexes have not gained widespread acceptance, and conventional density measures are still the norm. Several analyses of the relations between density and built form suggest that their interaction is richer and more complex than generally appreciated. Some previously conventional wisdom, e.g that higher densities save land and reduce development costs, has already been exploded. But density measures continue to be used in a very simple way, and even some preceding studies imply simple and relatively fixed relations between densities and dwelling types. It is this assumption that the following analysis will test.