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Urban Population Density Patterns and Change in Ireland, 1901-1979

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Précis: There were major changes in the population geography of the three largest cities in the Republic of Ireland during the twentieth century. Population densities in inner city areas have declined rapidly and most growth has been in suburban developments on the peripheries of the cities. Clark's (1951) negative exponential curve provides a very good fit to the population densities at each census year, and the changing patterns are summarised by the parameters of the model. Dublin especially has changed very quickly although its density was not particularly low by international standards about 1970. There are a number of problems associated with the present density patterns and these deserve urgent consideration.

I INTRODUCTION

This paper is concerned with the patterns of population density and change in Dublin, Cork and Limerick during the years 1901-79. This time period covers the evolution of the cities from compact, dense settlements to relatively mature ones. It is also the time during which their populations grew most rapidly (in the case of Dublin from about 352,000 in 1901 to some 870,000 in 1979, with smaller increases in Cork and Limerick). The study of population density is of importance because many of the problems which the cities are presently experiencing (inner city decay, suburban sprawl, traffic congestion, administrative and planning difficulties) are related to it, and density patterns must be considered in any comprehensive plans for the cities' improvement.

The analysis is based on mathematical models of urban population density which were developed in other countries, and these are described in the next section of the paper. The data for the three cities are then considered. Each of the cities is examined in turn and comparisons are made with densities in foreign cities. Finally, the implications of the trends are considered.

II POPULATION DENSITY MODELS

The first major model of urban population density was developed by Colin Clark in 1951. He established that gross densities outside of the central business area could be described by a negative exponential curve of the form:

$$d_x = d_o e^{-bx} \quad (1)$$

where d_x is the population density at distance x from the city centre, d_o is the estimated density at the centre, b is an empirically-estimated coefficient, and e is the base of the natural logarithms. This model is intrinsically linear and can be estimated by ordinary least squares after conversion to natural logarithms:

$$\ln d_x = \ln d_o - b_x \quad (2)$$

Many subsequent studies have shown the model to have a high degree of validity (Berry, Simmons and Tennant, 1963; Edmonston, 1975; Glickman and White, 1979). It is also easily interpreted and very useful for longitudinal and comparative studies. Winsborough (1963) has termed the d_o value *congestion* since it estimates the crowding of residents at the city centre. In the western industrial city this value declines over time as inner city areas become depopulated, but in the cities of the developing world, the trend has been for central populations to increase over time (Berry, Simmons and Tennant, 1963; Vaughan and Schwirian, 1979). The b-coefficient or density gradient was called *deconcentration* by Winsborough (1963). Higher values indicate a steep decline in density with distance from the city centre while lower values represent a more even distribution of population. Empirically, b-values have declined rapidly in most western cities over the past century (for example, in Chicago from 0.91 in 1860 to 0.40 in 1900 and 0.18 in 1950) although in the cities of the Third World, they have tended to remain constant (Berry, Simmons and Tennant, 1963).

Many alternative density models have been proposed (for a review, see Zielinski 1979 and 1980). Two of these are extensions of Clark's negative exponential curve. Tanner (1961) and Sherratt (1960) independently argued that city densities decline exponentially as the square of distance:

$$d_x = d_o e^{-cx^2} \quad (3)$$

As with Clark's model this curve is easily converted to natural logarithms and estimated by least squares. In its raw form it describes a half-bell curve and its logarithmic version a half parabola, concave downwards. This often produces a better fit to empirical density profiles than does the linear logarithmic version of Clark's model (2).

Both of these models are incapable of describing the density crater which is found at the centre of many cities because of the dominance of non-residential land uses. In order to allow for this, Newling (1969) proposed a model which combines both the linear term of Clark and the squared distance term of Tanner and Sherratt in the exponent of the equation:

$$d_x = d_o e^{bx - cx^2} \quad (4)$$

In its logarithmic form, this equation describes a first-degree polynomial curve which can fit the lower densities at city centres and the density peaks in the older areas outside the CBD which are typical of many cities. Obviously, Newling's model subsumes both the Clark and Tanner-Sherratt ones. When his c-coefficient is zero, his model is identical to Clark's, while a zero b-coefficient produces the Tanner-Sherratt curve. Newling's model is particularly useful for longitudinal studies of cities and he has expanded it into a mathematical model of urban growth by specifying the parameters for cities in a youthful, mature or old age stage of development (Newling, 1969).

III DATA

Small area census data are available for the three cities for the period 1901-1979. However, the ward boundaries were modified several times and the county boroughs and suburbs were expanded as the cities grew. The major changes are described below.

Dublin

In 1901 and 1911 Dublin County Borough covered 12.4 square miles and was subdivided into twenty wards. By 1926 it expanded to 13.1 square miles, mainly through the extension of the north docks, and comprised the same twenty wards. In addition, four urban districts, Pembroke, Rathmines and Rathgar, Blackrock and Dun Laoghaire, were defined as "adjoining" the county borough. These comprised another ten wards covering 9.1 square miles. However, contemporary maps and the pattern of later population increase indicate that all of these wards were not completely built up by then. Only the four wards in Pembroke and Rathmines and Rathgar, and Blackrock No. 1 were fully developed and contiguous to the city proper. Howth was also constituted as an urban district in 1919 but, like Dun Laoghaire, it was separated from the contiguous built-up area. Accordingly,

for the censuses of 1901, 1911 and 1926, Dublin was subdivided into 25 smaller tracts. Gross population densities (persons per acre) were calculated for each of the wards, together with the distance in miles between the centre of each ward and the city centre (O'Connell Bridge). These two variables are the basic data for the models described above.

In 1930, the city boundary was extended considerably. Pembroke, Rathmines and Rathgar and the villages of Terenure and Killester were incorporated into the County Borough. It then covered 29.3 square miles and in 1936 was subdivided into 33 wards. Some of the central wards were unchanged from 1926 but most of the remainder were modified considerably. In addition, Dun Laoghaire was constituted in 1930 as a borough with nine wards covering 6.5 square miles. Population data for the new sub-areas were published in the 1936 Census. By then Blackrock had been largely developed so the contiguous city covered 36 wards altogether (33 in the Borough and three in Blackrock). The 1936 Census also contained the numbers of people living in the revised wards in 1926. Edmonston (1975) has suggested that the parameters in Clark's model may be affected by annexations on the outskirts of cities although the model seems fairly robust overall. Some insight into the effect of boundary extensions and ward modifications can be gained by comparing the parameters for the two sets of 1926 data (and for three later censuses when there were major annexations and/or revisions).

The Register of Population in 1941 did not contain small area data. By 1946 Howth Urban District and a part of Crumlin were incorporated into the city. It then covered 34.2 square miles and was sub-divided into thirty-three wards which were changed considerably from the 1936 ones. The borough of Dun Laoghaire was also joined to the city by a continuous built-up strip, so on the coast the city stretched from Howth on the north to Killiney on the south side. The city did not extend as far as this away from the coast, but it was again spreading beyond the borough boundaries. These ward divisions were used again in the 1951 Census, and, in addition, contiguous district electoral divisions were classified as suburbs. Parts of five DEDs on the north side, seven on the south side and four adjoining Dun Laoghaire were involved.[1] The Census also gave the 1946 populations of these suburbs and these data show that all but two (Drumcondra Rural and Palmerston) were developed by the earlier date.

1 The Census does not indicate the areas of those DED parts which are classified as suburbs in 1951 or later, but it lists the townlands which are involved in whole or part. In the present study, the townland parts were estimated by reference to the complete townlands nearby and the general pattern of suburban spread. These townland parts were not treated individually but were aggregated with the complete townlands to DED level, so if some areas were under-estimated they were probably balanced by others which were over-estimated. The resulting density estimates had a lot of context validity when compared to nearby areas, and the error involved is probably very slight.

In 1953, parts of 10 DEDs were incorporated into the County Borough, extending its area to 44.6 square miles. Accordingly, for the 1956 Census, Dublin contained 42 wards, with another nine in Dun Laoghaire Borough and fourteen suburban DEDs. The area and ward boundaries were unchanged for the 1961 and 1966 Censuses but the parts of the DEDs defined as suburbs were expanded as the city grew and one more suburban district (Glencullen) was included. In 1970, the most recent small area revision was made. This divided the County Borough into 141 wards and Dun Laoghaire Borough into 21. The DEDs of Dublin County were also redrawn and the suburbs redefined. Parts of six DEDs on the north side, 20 on the south side (in whole or part) and eight near Dun Laoghaire were classified as suburbs. This gave a total of 196 small areas for which data in 1971 (and 1966) were published. In the 1979 Census suburban areas were not identified. In the present study all of the 196 areas were treated as comprising the built-up city area for the purpose of fitting the density curve. In places, this overestimated the spread of the city by including entire DEDs where only parts were covered by suburbs in 1971, but it provides an indication of the changes which occurred during the 'seventies.

Thus, there are 15 data sets for the Dublin area for the period 1901-79 (11 for the census years and four backdated sets after major boundary or ward revisions). Only those wards within the built-up area of the city at each census year (except 1979) were included in order to avoid over-estimating the spread of the urban area.[2] This omits discontiguous dormitory towns and the rural areas from which commuting occurs. This is a conservative interpretation of the urban area but it should reflect the physical spread of the city proper and minimise the distorting effects of sparsely populated peripheral areas on the parameters of the models.

Cork and Limerick

There were far fewer boundary changes in Cork and Limerick. From 1901 to 1951, Cork County Borough covered 4.2 square miles and was divided into seven wards. From an early stage, however, the city was spreading outside its boundary, and by 1936 the Census identified suburbs to the south-west and south-east of the borough. There was also large-scale development to the north-west in St. Mary's DED. These three additional areas extended the city to nine square miles. In the 1951 Census five DEDs were defined as suburbs and these were back-dated for 1946. In 1955 parts of three of these suburban DEDs were added to the County Borough, extending it to

2 The numbers of observations for each year are given in the seventh Column of Table 1. Any discrepancies are due to the exclusion of wards which were clearly not developed by the year in question, e.g., in 1971, Artane G contained 7,191 persons, but it had a population of only 4 in 1966 and so was omitted from the 1966 profile.

5.2 square miles, and in the 1956 Census one additional DED was classified as a suburb. This brought the total of sub-areas to sixteen and the area of the city to 18.4 square miles. There were no changes for the 1961 Census but in 1965 the County Borough was extended to 14.4 square miles. It then contained 11 wards and parts of two DEDs were defined as suburbs for the 1966 Census. In 1970 the Borough was divided into 74 wards and these divisions, with two suburban DEDs, were used in the Censuses of 1971 and 1979.

From 1901 to 1950, Limerick County Borough covered 3.7 square miles with eight wards. In 1950 one DED was added to it, extending it to 7.4 square miles. These nine sub-divisions were used in the 1951 and 1956 Censuses, and parts of two DEDs were also defined as suburbs for the latter. There were no further changes until 1970, when the Borough was divided into 37 wards. These were used in the 1971 and 1979 Censuses, with parts of five adjoining DEDs classified as suburbs.

As in Dublin, gross population densities were calculated for each of the wards and suburban DEDs for each census year. For the 1979 Census, the entire suburban DEDs were used rather than the parts defined for the 1971 Census. Straightline distances were measured between the ward centres and the city centres (mid-points on St. Patrick Street and O'Connell Street for Cork and Limerick respectively), giving a total of 12 data sets for Cork and 11 for Limerick.

IV DUBLIN

In 1901, Dublin was a very compact densely-populated city. The built-up area (as defined above) spread over only 18.2 square miles and the gross population density was over 19,000 per square mile (Table 1). The density in those wards whose centres were within a half-mile of O'Connell Bridge was three times as high (90 persons per acre or almost 58,000 per square mile).[3] But the highest densities in the city were not in the centre but in the nearby areas. Wards like Wood Quay (130 persons per acre), Mountjoy (112) and Inns' Quay (110) contained huge numbers of people in the small houses of their streets and lanes and the tenements and slums of their decayed Georgian terraces. Densities declined very rapidly to the outskirts of the city and areas like Glasnevin on the north side and Pembroke East to the south had gross densities of only seven and thirteen

3 Up to 1936, there were four wards within a half-mile of the centre (North City, Royal Exchange, South City and Trinity) and these covered 372 acres. From 1936 to 1966, there were four redrawn wards comprising 742 acres (North City, Rotunda, Royal Exchange and Mansion House), and since 1971 there are seven wards covering the same area. The continuity in the population trends seems very strong and the effect of the ward changes is probably very slight.

Table 1: *Gross population density in the Dublin Metropolitan Area 1901-79*

Census year	*Area (sq. mls.)*	*Density (persons per acre)*	*Central density*	*Maximum density*	*Distance from centre (mls.)*	*Negative Exponential Model*			
						N	d_o	*b*	*r*
1901	18.2	30.2	90.3	129.9	0.9	25	150.9	-1.10	.87
1911	18.2	32.2	80.0	138.3	0.9	25	146.5	-1.04	.89
1926	18.9	32.5	68.3	139.3	0.9	25	135.9	-.95	.88
1926[a]	30.0	21.2	68.3	191.9	0.7	34	159.5	-1.20	.87
1936	31.0	24.2	63.3	185.1	0.7	36	99.8	-.76	.73
1936[a]	36.0	21.1	87.4	164.2	0.6	36	87.9	-.64	.78
1946	66.0	13.7	70.3	148.6	0.6	55	54.9	-.46	.71
1951	69.4	14.3	62.0	134.8	0.6	57	55.2	-.43	.72
1951[a]	74.7	13.4	62.0	134.8	0.6	65	40.9	-.41	.59
1956	74.7	13.6	44.3	109.6	0.6	66	40.8	-.37	.63
1961	75.8	13.7	38.4	100.9	0.6	66	40.4	-.34	.63
1966	77.6	14.8	32.1	87.7	0.6	66	38.5	-.30	.58
1966[a]	85.1	13.5	32.1	107.5	0.5	195	50.6	-.35	.54
1971	85.1	14.3	26.0	95.7	1.6	196	43.7	-.27	.52
1979	—	—	19.0	78.8	1.6	196	39.7	-.25	.53

[a]Using the wards and boundaries defined for the following census.

persons per acre although both wards were within two miles of O'Connell Bridge.

Clark's negative exponential model (1) produced a very good fit for these 1901 data with an r-squared of .76 (Table 1).[4] This is considerably better than a simple linear model (r^2 = .62) or the Tanner-Sherratt model (r^2 = .63) although the differences are not statistically significant. This pattern of fit remained constant between 1901 and 1951. For each of the eight census years in this period, the Clark model provided by far the best fit to the data with an average difference in explained variation between it and the linear model of .17 and an improvement on the Tanner-Sherratt curve of .13. The differences are not statistically significant in any case. The chief drawback of Clark's model is the over-estimation of the central density. In 1901 the central wards averaged 90 persons per acre while the model estimated it at 151 (Table 1). This is because of the higher densities in the zone-in-transition and the comparative density crater at the centre which was starting to appear by 1901. Newling's model (4) was designed for this pattern, but the coefficient for the distance-squared term was not significant for the Dublin data. The sign of the coefficient was consistent with his mathematical model of city growth, however, and would classify Dublin's density profile as being at a "youthful" stage of development.

During the 10 years to 1911, the four central wards lost population at an annual rate of 1.2 per cent (Table 2) and by the census of 1911 their gross density had fallen to 80 persons per acre. In contrast, most of the surrounding wards experienced population increase and conditions in the slums and tenements became even worse. The highest density occurred in the Wood Quay ward which was almost a mile from the city centre. The greatest rates of increase were in the suburban wards, however, particularly on the north side in the Glasnevin-Drumcondra-Clontarf areas. These changes in the density profile are reflected in the parameters of the negative exponential model (Table 1). Both coefficients decreased as the profile flattened and this pattern has continued almost without interruption to the present day. These trends continued over the next fifteen years. The central area populations declined at an annual rate of one per cent while most of the surrounding wards stayed fairly stable or even increased slightly. The Mountjoy and Rotunda wards, the home of some of the worse tenements in the city, had gross densities of 126 and 134 persons in 1926, and Wood Quay's density was 139. All of the suburban wards had substantial increases also. The b-coefficient for the Clark model fell below unity for the first time for the 1926 profile and the estimated central density continued to decrease.

The boundary extension and revision of the 1930s allow the first oppor-

4 All of the regressions in Table 1 are significant at the .001 level.

Table 2: *Annual rates of population decrease in city central wards, 1901-79*

Period	*Dublin*	*Cork*	*Limerick*
1901-11	1.21	1.44	+0.22
1911-26	0.96	0.69	0.37
1926-36	0.75	1.05	1.20
1936-46	2.15	1.11	2.41
1946-51	2.48	2.17	4.12
1951-56	6.51	5.51	7.43
1956-61	2.83	5.94	4.22
1961-66	3.48	3.36	No data
1966-71	4.16	6.21	7.13
1971-79	3.83	5.45	2.57

tunity to examine the effect of these changes on the parameters of Clark's model, as the 1926 populations in the revised wards were included in the 1936 census. The splitting of the Mountjoy ward into two smaller areas meant that most of its high-density tenements were concentrated into a smaller area, and the new Mountjoy ward had a 1926 density of 192 persons per acre. In addition, the suburban extensions produced lower gross densities in the peripheral wards. These two factors combined to produce a considerably steeper profile for the back-dated data than was estimated from the 1926 Census (Table 1). This shows the effect of changes in scale on the parameters of Clark's curve and would seem to validate the earlier argument in this paper for an accurate definition of the built-up area of the city to calibrate the model at each census.

During the decade 1926-36, the central populations decreased at an annual rate of 0.75 per cent while the suburbs continued to expand. The early 'thirties brought the Corporation's schemes for slum clearance in the central area and the rehousing of the inhabitants in large estates on the outskirts of the city. The first of these to be completed were in Crumlin to the south-west and Cabra to the north-west of the centre (Johnson, 1974). By 1936, therefore, the density in the central wards had declined by almost a third from its 1901 level, and the surrounding wards had stabilised or even decreased slightly from their 1926 peaks. These changes are again reflected in the continued decrease in both coefficients for the density profile. The fit of the model to the 1936 populations in the revised wards of the 1946 census is fairly close to the first 1936 curve, although it is a little flatter because of the addition of suburban areas.

By 1946, the slum clearance schemes were having a greater effect. All of the densely-populated wards of the inner city lost population during the preceding decade and there was a movement of almost 40,000 people into the Crumlin-Kimmage area. The central ward populations continued to decrease also (Table 2). The building of privately-developed suburbs to the north and south accelerated and spread outside the city boundary. The co-efficients describing the density profiles in 1946 and 1951 again reflect these trends with falling central densities (which are quite close to the calculated densities for those years) and smaller exponents which show the flattening of the curve.

During the 'fifties, the rate of change in the city became even faster. The population of the central area declined by almost thirty per cent during the period 1951-56. This was partly because of the continuing rehousing of people in the developing Corporation estates (at this time mainly Ballyfermot and Finglas) but probably also because of emigration from the state which was particularly heavy during the 'fifties. There was also the beginning of the post-war office boom in central Dublin which brought greater competition

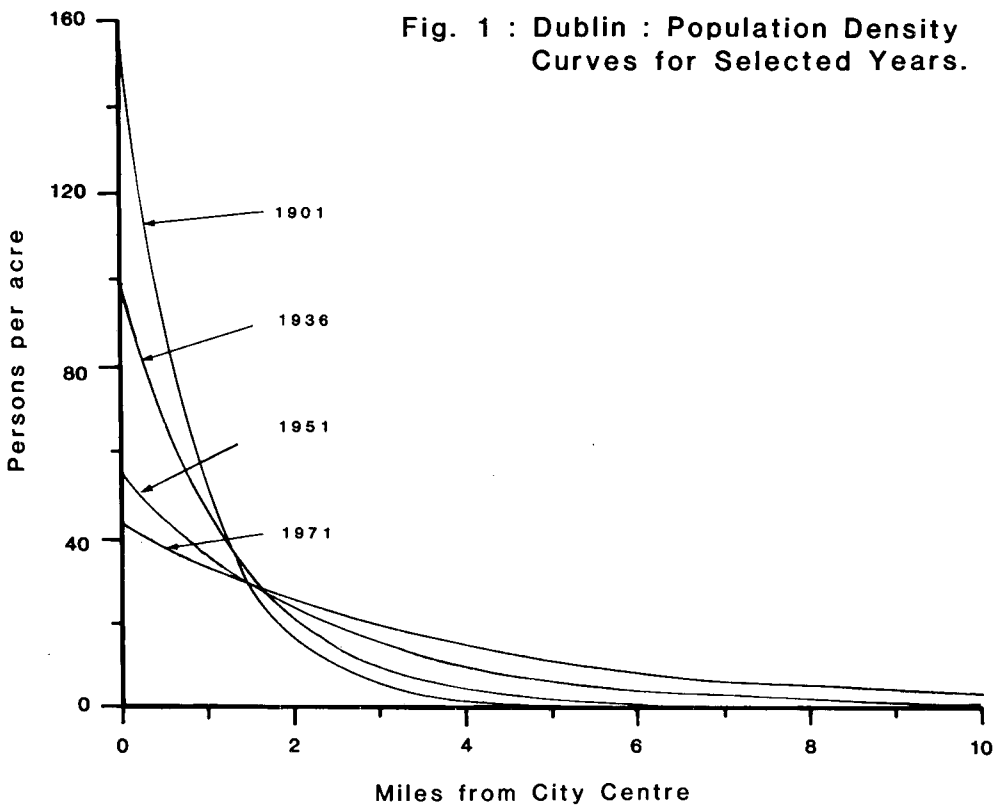


Fig. 1 : Dublin : Population Density Curves for Selected Years.

for space and the replacement of housing by commercial land uses. By 1966 the central population was only half that of 1951 and the density in the area was lower than the overall city density in 1911 or 1926. Outside of the core, population densities also fell. The highest ward density, in Mountjoy, exceeded one hundred persons per acre until 1961 (or 1966 with the redefined wards – see Table 1), but densities in the adjacent areas were considerably lower than that. Further out, the pre-war suburbs were stabilising or losing population during the 'fifties and 'sixties, but each successive census showed the outward spread of newer suburbs and the population growth in them. The estimated coefficients for the density profiles continued to reflect these trends, with declining central densities and lower exponents which indicate a further flattening of the curve. (In fact, a simple linear model provides a slightly better fit for the five data sets between the redefined wards in 1951 and those in 1966. The difference in explained variation averages only .026 and is not significant. The linear coefficients also reflect the changing pattern with a decline in the intercept from 53.3 in 1951 to 39.0 in 1966, and a change in slope, which here represents the decrease in persons per acre with each mile from the centre, from -8.4 in 1951 to -5.0 in 1966).

The ward revision of 1970 produced some changes in the density statistics. The central density in 1971 fell to 26 persons per acre, a decline of 19.1 per cent since 1966. The highest density and the estimated central density were higher than in 1966, but they were both considerably lower than were the 1966 densities in the redefined wards. By 1979, the central density fell to only 19 persons per acre, or only one-fifth of what it had been at the beginning of the century. The highest ward density was also at an all-time low of 79 persons per acre and this was well outside the centre in the Dolphin's Barn area (Ward Usher's D). For the reasons given earlier, the overall city density could not be estimated, but it cannot have been higher than thirteen or fourteen persons per acre. The fitted density profile includes peripheral areas which were not developed in 1979 and so it is somewhat distorted, but the exponent of -.25 is lower than the 1971 coefficient and reflects the continuing trend. This profile is by far the flattest which has been fitted to the Dublin data.

Thus, the density patterns of the Dublin area parallel those of most other Western industrial cities during the twentieth century. The density at the centre has fallen continuously while the suburbs have spread over ever-larger areas; in Winsborough's terms, congestion has declined while deconcentration has become increasingly important. The reasons, as in other cities, were a combination of market processes in land and buildings, housing and construction policies at corporation and government level, and transportation changes, particularly the spread of private motor cars. The changes have brought many improvements in living conditions compared to the past,

but they have also generated several real or potential problems which require urgent attention.

Sectoral Differences in Dublin

The patterns described above have not distinguished any sectoral variations, but there have always been marked differences between the north and south sides of the city. The north side has a higher proportion of local authority housing and has always had higher densities, both at the centre and in the suburbs. The south side has more private developments and has spread over larger distances on the coast and to the foot of the Wicklow mountains.

These differences are summarised by the density profiles of the two sides of the city (Table 3). These show that the estimated central densities have always been higher on the north side, at times almost twice as high as those of the south. Both have declined continuously, and the decrease has been far more rapid in the north so that by 1979 the difference in intercept was very small. The trends in the b-coefficient have been identical. That for the north has always been higher than the southern coefficient, reflecting the

Table 3: *Sectoral population density patterns in Dublin, 1901-79*

	North				*South*			
Census year	*N*	d_o	*b*	*r*	*N*	d_o	*b*	*r*
1901	10	222.3	-1.55	.92	15	131.8	-.91	.91
1911	10	213.1	-1.42	.93	15	126.1	-.87	.90
1926	10	186.4	-1.23	.91	15	117.3	-.81	.89
1926[a]	14	180.7	-1.29	.89	20	142.3	-1.13	.85
1936	14	187.7	-1.19	.84	22	73.3	-.57	.70
1936[a]	17	84.8	-.70	.80	19	79.3	-.52	.76
1946	21	83.6	-.73	.85	33	48.5	-.37	.64
1951	22	81.6	-.70	.85	35	51.4	-.36	.71
1951[a]	26	63.4	-.72	.73	40	42.2	-.36	.61
1956	26	57.2	-.59	.78	40	40.2	-.32	.60
1961	26	56.0	-.54	.76	40	38.5	-.30	.60
1966	26	53.6	-.45	.72	40	37.7	-.26	.58
1966[a]	78	78.4	-.62	.63	117	49.5	-.30	.58
1971	79	56.5	-.40	.56	117	41.1	-.24	.52
1979	79	44.4	-.30	.50	117	38.4	-.23	.55

[a]Using the wards and boundaries defined for the following census.

Table 4: *Gross population density in Cork, 1901-79*

Census year	*Area (sq. mls.)*	*Density (persons per acre)*	*Central density*	*Maximum density*	*Distance from centre (mls.)*	*Negative Exponential Model*			
						N	d_o	*b*	*r*
1901	4.2	28.4	59.5	88.6	—	7	77.7	-1.38	.85
1911	4.2	28.6	51.5	75.6	—	7	67.7	-1.19	.79
1926	9.0	16.0	48.1	68.5	0.6	10	76.8	-1.64	.94
1936	9.0	17.2	43.3	64.9	—	10	68.5	-1.42	.93
1946	16.2	10.4	44.1	62.1	—	12	74.4	-1.57	.94
1951	16.2	10.8	39.5	55.6	0.6	12	67.8	-1.47	.93
1956	18.4	9.7	29.8	39.3	—	16	53.5	-1.25	.90
1961	18.4	9.8	21.9	33.7	0.5	16	44.2	-1.13	.85
1966	19.2	10.2	18.5	33.3	0.5	13	31.4	-0.95	.85
1966[a]	22.7	8.7	25.7	94.6	0.4	76	76.1	-1.21	.79
1971	22.7	9.2	18.6	90.8	0.4	76	60.9	-0.99	.72
1979	—	—	11.9	81.1	0.4	76	49.1	-0.79	.66

[a]Using the wards and boundaries defined for the following census.

steeper density profile on the north side, but it has also declined far more rapidly and by 1979 the coefficients were fairly similar. If present trends continue, the intercepts and coefficients for both sides should continue to converge.

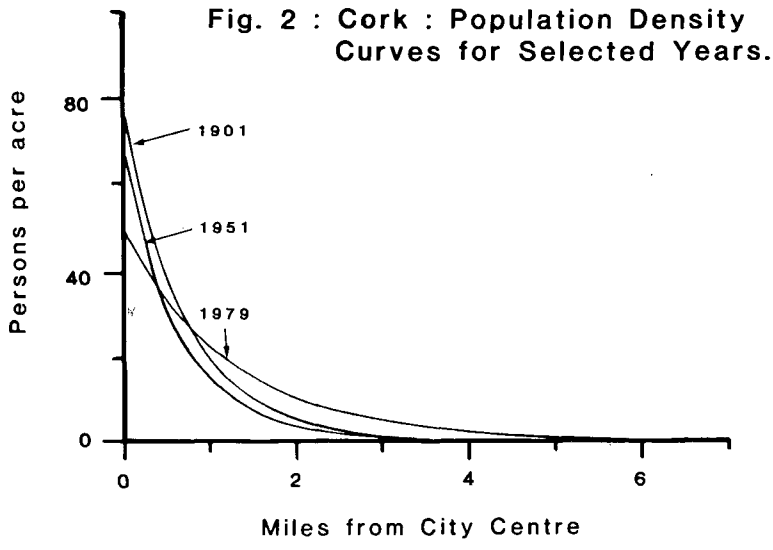
V CORK AND LIMERICK

The trends in Cork and Limerick were similar to those in Dublin. There was a five-fold increase in the built-up area of Cork City between 1901 and 1971 and a three-fold decline in the gross population density throughout this area (Table 4). As in Dublin, the decline was particularly heavy in the central area (Table 2).[5] The central densities were always lower than in Dublin, because Cork had developed as a merchant city and commercial land uses had precedence in the core. The phases were similar to Dublin's also: "natural" population loss at the beginning of the century through pressure from non-residential land uses, followed by the slum clearance schemes of the 'thirties, their completion during the 'fifties, when with emigration, the population loss was particularly heavy, and since the mid-sixties, the problems of traffic congestion, vandalism, blight and job losses have greatly reduced the residential population in the city centre. The highest density in any ward in the city has also been generally lower than in Dublin. For five of the census years, the highest density occurred in one of the central wards and since 1966 the smaller wards of the boundary revision have produced higher maximum densities, but the general trend, as in Dublin, has been for a continuous decline in this statistic also. The decline of the centre has been paralleled by the spread of the suburbs. Private developments were widespread on the south-side during the 'twenties and 'thirties while much of the corporation housing was built to the north of the river Lee. This pattern has persisted to the present and the entire north-west quadrant of the city now consists almost exclusively of public housing estates. Since 1967, much of the residential development in Cork has been concentrated in the satellite towns like Ballincollig and Carrigaline (which are outside the scope of this study), so the suburban sprawl has not been as severe in Cork as it has in Dublin.

The negative exponential model produced very good fits to Cork's density profile (Table 4).[6] In general, the intercept estimating the central density

5 Cork's central area is clearly defined by the two channels of the River Lee. From 1901 to 1966, this comprised the Centre, North Centre and South Centre wards and covered 107 acres (reduced after 1946 to 94 acres). Since 1971, there are two wards, Centre A and B, covering 137 acres.

6 The fits of the 1901 and 1911 data are significant at the .01 level. All of the others are significant at the .001 level.



has been higher than the actual density in the area, but the coefficient has declined consistently as the population has fallen. The exponent has always been higher than in Dublin because of the smaller spread of Cork. It does seem to have been affected by the addition of suburban areas, as in 1926 and 1946, and by the boundary revision of 1970, but in general it shows a decline throughout the century as the suburbs spread and the density profile flattened.

Being the smallest of the three cities, Limerick has always been the most compact. Between 1901 and 1971 its built-up area had a four-fold increase from 3.7 to about 13 square miles. Simultaneously, its overall gross density was more than halved. The density at the centre was slightly higher than Cork's and the pattern of decline was almost identical.[7] The highest density in Limerick, in the Irishtown ward, was higher than Cork's maximum until 1966, although it also had decreased consistently since 1901. Once again, the negative exponential model provided an excellent fit to Limerick's density profile.[8] The intercepts have continuously overestimated the central densities but they have declined consistently with them. The b-coefficients were always higher than the exponents in Dublin and Cork, because of the smaller area of the city but they have changed to reflect the suburban spread and the flattering of the profile.

7 From 1901 to 1966, the Shannon and Custom House wards were taken as the centre. These totalled 108 acres until 1936 and 93 acres since then. The redefined Shannon A and B and Custom House wards, covering 103 acres, have defined the centre since 1970.

8 Up to 1936 the fits are significant at the .01 level. Since then they have reached the higher level of .001.

Table 5: *Gross population density in Limerick, 1901-79*

Census year	*Area (sq. mls.)*	*Density (persons per acre)*	*Central density*	*Maximum density*	*Distance from centre (mls.)*	*Negative Exponential Model*			
						N	d_o	*b*	*r*
1901	3.7	16.0	61.4	103.9	0.4	8	130.7	-2.76	.80
1911	3.7	16.1	62.8	89.6	0.4	8	120.7	-2.60	.79
1926	3.7	16.5	59.4	94.8	0.4	8	114.9	-2.50	.77
1936	3.7	17.2	52.6	90.3	0.4	8	103.3	-2.33	.82
1946	3.2	20.8	47.9	67.0	0.4	8	94.4	-2.03	.89
1951	7.4	10.8	38.8	61.7	0.4	9	88.9	-2.11	.94
1956	8.4	9.6	26.7	47.2	0.4	11	69.1	-2.00	.96
1961	8.4	9.6	21.5	36.1	0.4	11	52.6	-1.75	.95
1966[a]	13.2	7.0	26.7	49.8	0.5	41	75.9	-1.96	.83
1971	13.2	7.4	18.4	43.4	0.5	41	48.5	-1.41	.77
1979	—	—	15.0	36.1	0.5	42	37.3	-1.16	.79

[a]The 1966 Census did not contain ward data for Limerick. This uses the wards and boundaries defined for the 1971 Census.

Thus, the pattern of growth and change in Cork and Limerick has been almost identical to that of Dublin. The market dynamics underlying the change and the role of the local authorities seem also to have been very similar. It will be argued below that the practical implications of these changes in all three cities require urgent attention.

VI SOME INTERNATIONAL COMPARISONS

The density statistics and distances in this paper have been expressed in acres and miles, the most commonly used units in Ireland. In general, foreign studies express densities in square miles or kilometers, or hectares. To facilitate comparisons, all density functions are here converted to square miles and miles distance.

The best-known longitudinal study of a single city is of Chicago (Newling, 1966; Rees, 1970). This shows that Chicago's density gradient was less than unity as early as 1860. In contrast, Dublin's gradient did not fall below one until the 1920s. The estimated central density in Chicago increased after 1860 and reached a peak of 100,000 in 1900 and 1910. The intercept in Dublin's profile about that time was very similar (96,576 in 1901). Since 1910, Chicago's intercept and slope have continued to decline but at a con-

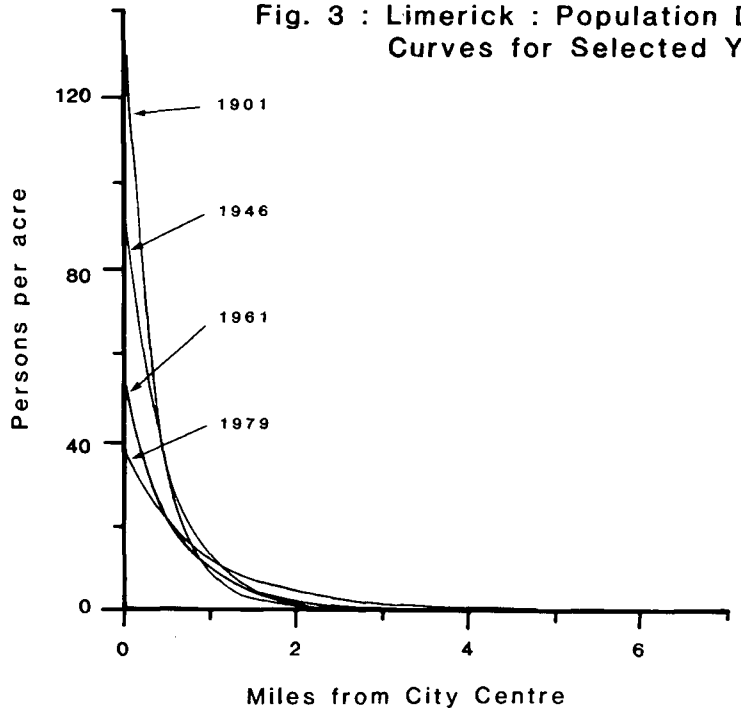


Fig. 3 : Limerick : Population Density Curves for Selected Years.

siderably slower rate than Dublin's, and the estimated central density has remained far higher. In 1950, for example, Chicago's central density was 63,700 persons per square mile compared with 35,328 in Dublin. The gradient in Chicago was lower (-.18 versus -.43), showing that the higher central densities declined far less rapidly with distance from the centre than did Dublin's (the coefficients indicate that density in Chicago at a distance of four miles from the centre was 30,759 persons; Dublin's equivalent density was only 6,326). Chicago is one of the highest density American cities and there are many which have lower central densities and gentler gradients than Dublin, but the rapidity of change in Dublin and the short time in which it has reached American density standards is striking (see the trends reported in Edmonston, 1975).

Density parameters from two recent studies of other countries about 1970 are given in Table 6 (the Mills and Tan paper did not include estimated central densities). There are very few cases of density curves being fit to cities as small as Limerick, but the 1971 coefficients for Dublin and Cork can be compared with similar-sized cities in the other countries. The profile in Dublin appears to have been very similar to British and German cities

Table 6: *Selected density profiles, c. 1970*

	Year	d_o [a]	b [b]
Dublin	1971	28.1	-.27
Cork	1971	38.1	-.99
British cities of .5-1 million	1971	26.1	-.25
British cities of .25 million or less	1971	13.9	-.23
German cities of .5-1 million	1970	24.4	-.31
German cities of .25 million or less	1970	28.3	-.74
Japanese cities of .5-1 million	1970	45.4	-.49
Japanese cities of .25 million or less	1970	23.4	-.65
Korean cities	1970		-1.07
Latin American cities	1970		-.30
Brazil	1970		-.25
Mexico	1970		-.45
USA	1970		-.20

[a] In thousands per square mile.

[b] In terms of miles.

Sources: Britain, Germany and Japan: Glickman and White, 1979; Korea, USA and Latin America: Mills and Tan, 1980.

about that time. Japanese cities had considerably higher central densities, similar to those in Dublin twenty years previously, and a steeper profile. The density gradients in Korea were by far the steepest in 1970, while those of the United States were flattest. British cities of 250,000 people or less had considerably lower intercepts and gradients than Cork in 1971, but German and Japanese cities had profiles closer to the Irish one.

Thus, by 1970 the density patterns in both Dublin and Cork were similar to those in other cities in the Western developed world. Their densities were not especially low by international standards, although the speed with which Dublin has been transformed into a sprawling low-density city has been very rapid when compared with developments elsewhere.

VII DISCUSSION

Clark (1977) has suggested that the trends in many cities of flattening density gradients will result eventually in uniform densities over large urban areas with b-coefficients of zero. Los Angeles already has this pattern and there are "incipient signs" of it in other cities. The density in these cities has settled at 10,000 persons per square mile (about 16 persons per acre). Clark noted that, even with this low density, a city of one million people could still be accommodated within a circle of 5.6 mile radius, with undisturbed countryside outside it. The gross density in Dublin in 1971 was only fourteen persons per acre and the built-up area had spread to more than ten miles from the centre in places. It must also be remembered that the dormitory towns and commuting belt were specifically excluded from this study so the full area and population of the conurbation was underestimated. The same is true, to a lesser extent, of Cork and Limerick.

The most serious problems generated by the trend towards low-density cities are in transportation. It is inevitable that journeys for every purpose in outlying areas – work, shopping, education, recreation and even socialising – become longer and longer. This is particularly true in Irish suburban developments where there are generally long delays in providing work and services in areas after the housing has been completed. Public transport on fixed routes becomes increasingly inefficient in low density areas and suburbanites have to resort to their cars. It was estimated in Chicago about 1965 that a bus service became unremunerative when gross densities fell below an approximate level of 12,500 per square mile (20 persons per acre) (Clark, 1977, p. 366). Greater dependency on private transport in cities is a worldwide trend (Thomson, 1977), and this has also been occurring in Irish urban areas (Foster, Powell and Parish, 1980). Without the development of motorways, there is inevitably congestion in the city centre. The larger buses are particularly affected by congestion (CIE estimated that average bus speeds in

central Dublin were halved from fourteen to seven miles per hour between 1970 and 1977), and the resulting deterioration in public transport encourages more people to depend on their own vehicles, so exacerbating the problem. Killeen (1980) has discussed the indecision in formulating and implementing a transport policy in Dublin during the 'seventies. The situation has improved over the past year with the establishment of the Dublin Transportation Authority and the introduction of bus lanes on several routes but the problem needs to be tackled at an earlier level. As long as the low-density land uses which generate higher transport needs are allowed to develop on the peripheries of cities, the problem will continue to deteriorate.[9]

A second problem is the administration of a city which becomes fragmented between several local authorities as it spreads beyond its legal boundaries. The continuous built-up area of Dublin described in this paper is split between three local authorities – the boroughs of Dublin and Dun Laoghaire and Dublin County Council. The outlying parts of the conurbation extend into Counties Wicklow, Kildare and Meath. The needs and priorities of the different areas are not always in harmony and there is no overall metropolitan authority which can reconcile conflicts of interest. In this situation, strategic planning becomes extremely difficult (see Hall, 1977).

The physical environment of a city is also affected by its areal extent. The climate of an urban area is different to a rural one in all aspects – temperature, humidity, precipitation, wind speed and solar radiation (Lowry, 1967). Some of these differences may be beneficial, e.g., generally higher temperatures (the "heat island" effect), but their net result is not fully understood and there is a possibility of large-scale global climatic change resulting from the continuous extension of metropolitan areas. Pollution levels in cities are higher than in the countryside, partly because of the concentration of polluting agents like cars and factories but also because of the climatic changes resulting from the built-up area (e.g., the "dust dome" which is caused by differential heating of the surface exacerbating the pollution problem in many cities). By international standards, Irish cities have been relatively pollution-free until recently, but there is evidence of increasing levels which may be causing health problems. Bailey, Kevany and Walsh (1981) have found significant relationships between sulphur dioxide levels in Dublin and social welfare claims for sickness absence during the winter of 1976-77. In a study of health admission data for the three winters between 1975 and 1978, Sweeney (1981) has analysed the effect of ground level concentrations of smoke and sulphur dioxide in the city. He found significant

9 There are ways in which public transport efficiency in low-density areas can be improved (e.g., by locating activities so as to generate two-way flows during peak periods) but the possibility of such comprehensive redevelopment in Irish cities is very slight. See White (1976).

correlations between respiratory and cardiovascular morbidity and sulphur dioxide levels in 1975-76 and smoke concentrations in 1976-78. The increasing importance of smoke may be due to the shift from oil to coal for home heating, and this trend looks likely to continue. There is a lack of comprehensive monitoring of the most deadly pollutants of all, vehicle exhaust emissions, in Irish cities, but there is evidence that it is an increasingly serious problem (Jamieson, 1981). Certainly, the recent derogation from the EEC directive on lead levels in petrol is not helpful in this respect.

There is no point in eulogising the high-density slum conditions of the inner cities in the early part of this century but the virtually depopulated central areas of the present time also have serious problems. There are many derelict sites and blighted areas in all three cities and the absence of a viable resident population has contributed to the present demoralisation and crime problems of the centres. All three local authorities are attempting to maintain the existing housing stock and build new houses, but their efforts have been troubled by the high costs involved and by pressures from other land uses. Private developers have concentrated on shopping and office construction to the exclusion of housing. The apartment block developments and gentrification that are occurring in Dublin will benefit the middle classes and wealthy rather than the traditional working-class residents of the area, and in Cork and Limerick even these developments are unlikely because of the small size of the cities. Clearly, only a major effort, such as that proposed by Bannon, Eustace and O'Neill (1981), will revitalise the city centres. Conversely, the suburbs also have their problems and are very far from the ideal living environments they once promised to be. The local authority estates suffer from social and economic deprivation, and many privately-developed areas have problems of poor design, lack of open space, and long delays in receiving community services like schools and shopping facilities (Bannon, Eustace and O'Neill, 1981). The problem of reconciling the conflicting demands of different parts of our cities, particularly in a time of financial stringency, is a major one.

It must be noted that part, at least, of Dublin's present low population density is due to the existence of many undeveloped spaces within the contiguous built-up city. This is less true of Cork and Limerick, where the potential for new development is far smaller. Speculation in building land and the withholding of it from the market to raise prices are clearly detrimental to the interests of the community as a whole, but although measures to control this were suggested in the Kenny Report of 1973, the three governments since that time have failed to tackle the problem. Without comprehensive land and transportation controls, it seems certain that the low density trends in Irish cities are going to continue.

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