VARIATION OF DEVELOPMENT STANDARDS AND REQUIREMENTS FOR SUBDIVISIONS OF DIFFERENT DENSITIES

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(1954)

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(1957)

SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE
DEGREE OF MASTER IN
CITY PLANNING

at the

MASSACHUSETTS INSTITUTE OF
TECHNOLOGY

May 1959

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ABSTRACT OF THESIS

VARIATION OF DEVELOPMENT STANDARDS AND REQUIREMENTS

FOR SUBDIVISIONS OF DIFFERENT DENSITIES

by Harold S. Kramer

Submitted to the Department of City and Regional Planning on May 25th, 1959, in partial fulfillment of the requirements for the degree of Master in City Planning

The objective of the thesis is to investigate and determine in what instances development standards and requirements can be varied according to the density of development.

The study consists of a review of selected development standards and requirements of which an investigation was made in an attempt to determine the significance of density as a criterion for varying standards and requirements. In appropriate instances, standards and requirements which vary according to density are suggested.

Certain of the selected standards and requirements can be varied according to density. There were other standards and requirements where variation according to density is not operationally practical. Some standards and requirements were investigated where variation according to density could not be established because of insufficient data. Investigation further determined that there is a set of density ranges within each of which standards are constant, and among which some standards vary.

In conclusion, it is recommended that in appropriate instances standards and requirements which vary according to density be formulated. It is further recommended that developments be classified into density types, specified by lot area and frontage requirements to which such formulated standards and requirements could be related. Subdivision regulations which include these formulated standards and requirements in the manner prescribed above would provide, in the writer's opinion, a clear guide to planning boards for both mandatory and discretionary actions. Further, such regulations could provide for the development of land more properly related to intensity of use.

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ACKNOWLEDGEMENT

I wish to express my sincere appreciation to the following people who have given me both constructive criticism and helpful guidance in the writing of this thesis....

Mr. William E. Barbour
Mr. Allen Benjamin
Prof. Roland B. Greeley
Prof. John T. Howard
Prof. Kevin Lynch
Mr. Thomas Rinaldo

....and Prof. Burnham Kelly, my advisor.

INTRODUCTION

The Problem

The use of discretionary powers by local officials to vary standards and requirements under local subdivision control regulations has been identified as a major source of difficulty between subdividers, developers, and reviewing authorities.[1] Too often a single set of standards and requirements, usually based on extreme conditions, are specified in the regulations, and broad powers are granted to lay planning boards to allow relaxations from this schedule at their discretion. The lack of a clear guide to local planning boards in their exercising of wide discretionary powers to vary standards may too often result in decisions based on mere whim and circumstance, rather than on sound planning practice.[2]

In order to limit the arbitrary use of discretionary powers by planning boards, it has been suggested that subdivision regulations specify standards and requirements which vary according to the density of development, e.g., the standards for width of roadway might be specified as 18' at densities of one family per net acre, and 26' at densities of seven families per net acre. Other variables are recognised.

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1. William E. Barbour, Improvement Requirements in Subdivisions, Thesis: M.C.P., M.I.T., 1957, p. 65.

2. Ibid., pp. 47-48.

which may be of importance in varying standards, e.g., aesthetic or design considerations, considerations of the locality or site in question of a technical nature, and considerations of over-all community needs as set-forth in a Master Plan. In this study, however, investigation will be made to determine in what instances standards and requirements can be varied according to density alone, i.e., density as the criterion for varying standards and requirements.

Objectives

This thesis will attempt to answer the following questions:

1. Can certain of the selected standards and requirements be varied according to density?
2. Are there some standards and requirements where variation according to density is not operationally practical?
3. Can a set of density ranges be established within each of which standards are constant, and among which some standards will vary?

The writer expects to find that:

1. Certain of the selected standards and requirements can be varied according to density.
2. There are other standards and requirements where variation according to density is not operationally practical.
3. There is a set of density ranges that can be established within each of which standards are constant, and among which some standards will vary.

<u>Scope</u>

No attempt will be made to discuss all standards and requirements, nor will all ranges of residential density be dealt with.

The thesis is concerned with single family homes on conventional lots ranging in density between seven families per net acre, and one family per two net acres. Investigation will be directed to a selection of development standards and requirements for streets, improvements, and the reservation of land for recreational purposes. More specifically, standards and requirements for the following items will be discussed:[3]

pavement width	street alignment
sidewalks	reservation of land for recreational purposes
curbing	sanitary sewerage
planting strip	water supply
right-of-way	storm drainage

Neither the procedural aspects of subdivision control regulations, nor other elements of subdivision which are not governed by these regulations will be discussed, e.g., zoning.

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3. Standards for the layout, pipe sizes, construction specifications, and other like considerations will not be discussed for sanitary sewerage, water supply, and storm drainage. The layout of these facilities is a substantial engineering problem which requires the competent advice of sanitary and civil engineers. Further, a determination of standards for these facilities depends considerably on technical considerations of the locality in question - soil quality, topography, water table, and the like.

Capital and maintenance costs for the items outlined previously are not developed in detail, as the major point of departure is the factor of density, rather than the factor of cost.

This thesis does not attempt to determine the full impact of proposed variations in the standards and requirements upon the total aspect of design in its broadest sense. The limitation of time necessitates a restricted scope for this thesis.

Approach

In order to determine in what instances standards and requirements can be varied according to density, the following approach will be taken: (a) to describe the purpose of standards and requirements and list those factors which determine their use, (b) to point out the significance of density to the factors which determine the standards and requirements, and (c) to propose ways of using density as a criterion for varying standards and requirements.

A review was made of published materials and recommendations of standards developed by recognised authorities in the field of land development and planning. Interviews with developers, officials, and interested agencies have also been used to give additional insight into these problems.

REVIEW OF DEVELOPMENT STANDARDS AND REQUIREMENTS

Standards for Pavement Width

Proper standards for the width of paved roadway are necessary to insure sufficient width for anticipated parking and moving lanes of traffic.[4] The factors which are most significant in determining standards for pavement width are: vehicular traffic conditions, parking requirements, and turning and backing movements of vehicles.

Of the traffic conditions anticipated on residential streets in developments within the density ranges chosen, volume of vehicular traffic, rather than speed and composition of traffic, is the most critical factor in determining standards for pavement width of moving lanes. The following chart indicates how standards for pavement width of moving lanes vary with vehicular traffic volumes:[5]

Design Speed	Traffic Volumes in Vehicles Per Hour			
30-50 m.p.h.	5-30	30-100	100-200	200 plus
Pavement width for moving lanes	18'	20'	22'	24'

4. Harold W. Lautner, Subdivision Regulations, (Chicago, Public Administration Service, 1941), p. 109.

5. American Association of State Highway Officials, A Policy on Geometric Design of Rural Highways, (Washington, D.C., AASHO, 1957), p. 223. The assumptions here include that traffic is primarily composed of passenger vehicles, and that the speeds on the street types considered in this study are not likely to exceed those ranges which are critical in effecting variations of standards for width of pavement for moving lanes. These assumptions are substantially reflected in the chart above.

Given that standards for pavements width of moving lanes vary with volumes of vehicular traffic, the next step of the analysis will attempt to determine what effect differences in density have upon this factor.

The volume of traffic on residential streets in subdivisions will vary with car ownership, use of the automobile, density of development, and the type and function of streets. In order to determine how traffic volumes vary with density, the following assumptions will be made: (a) Car Ownership and Use - at least one car per family, of which 0.4 cars will be expected to move during peak hours, (b) Street Types - minor streets will carry traffic generated primarily from abutting properties served. Feeder streets serve abutting properties and act as a collector for minor street systems.[6]

Given the assumptions above, traffic volumes on a minor residential street could be calculated using density as a measure of traffic generated.[7]

Density - families per net acre	7	6	5	4	3	2	1	0.5
Volume - Vehicles at peak	26	24	20	18	16	14	10	6

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6. National Committee for Traffic Safety, <u>Building Traffic Safety into Residential Developments</u> (Chicago, NCTS, 1949), pp. 9-10.

7. The figures derived above also assume a uniform 6:10 ratio of lot frontage-to-depth along a 2000' minor residential street. I assume lot frontage and width to be identical, and "full" development on both sides of the street.

On the basis of the previous discussion, it is apparent that the volume of traffic generated on a minor residential street within the ranges of densities chosen here does not call for varying standards for pavement width of moving lanes, i.e., specifying a "higher" standard at seven families per net acre, for example, and a "lower" standard at one family per net acre. A minimum width of 18' for moving lanes of traffic on minor residential streets seems sufficient.[8]

Traffic volumes on a feeder street will vary depending on the continuity of alignment, area and density of development served, and the layout of the feeder to other street systems and activity-centers to "attract" traffic. For any given area served by a feeder, we would expect varying conditions of vehicular traffic depending on the density of development. However, other variables, as outlined above, are significant in determining anticipated traffic volumes on a feeder street. Therefore, both generated and attracted traffic should be considered in determining potential volumes of traffic for feeder streets which, of course, vary with local conditions. For these reasons, the standards for pavement width of moving lanes on feeder streets are better related to volumes of traffic, rather than the factor of density itself.

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8. See footnote 4, p. 5, Supra., also see Chart on p. 5, which indicates how standards for width of moving lanes vary with vehicular traffic volumes.

The need for parking lanes on residential streets is significant in determining standards for pavement width.[9] Most authorities recommend at least one parking lane be provided in order to maintain two-directional traffic with a minimum of driver inconvenience.[10]

In single family residential subdivisions within the ranges of density chosen in this study, we may reasonably expect varying needs for curb parking. In developments at densities from seven to two families per net acre, for example, provisions for off-street parking on each lot could be made to accommodate up to two parked vehicles.[11] Cars in excess of this number would necessarily seek parking at the curb, which might occur frequently enough to justify the provision of one parking lane. Further, curb parking may be expected on most residential streets by delivery vehicles, visitors, and maintenance vehicles. For the densities mentioned above, the incidence of such temporary parking again seems sufficient to justify the provision of one parking lane in order to insure a maximum of ease for vehicular traffic movement.

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9. N.C.T.S., op. cit., p. 15. Most authorities recommend a minimum width of 8' for a parking lane.

10. Ibid. On minor residential streets, occasional weaving between parked cars is not considered undesirable from a standpoint of driver convenience. On a feeder street, however, this authority states that, "Desired freedom of movement could not be achieved if drivers must weave to avoid occasional parkers."

11. Assuming the typical case, i.e., direct access to, and parking on individual lots, a graphic analysis of varied house plans and driveway layouts were used to determine the area that could be reasonably utilised for off-street parking. In all cases, I assumed a minimum set-back of 30' and no parking at the rear of the structure, or in alleys at the rear of the lot.

In developments of less than two families per net acre, the need for curb parking is considerably lessened. The area available for off-street parking facilities on lots at these lower densities is increased, for wider lots permit the use of curved driveway layout, and modified "T" turn-arounds. The increased length of driveway and the additional area afforded by a turn-around permit up to four parked vehicles on the lot.[12] For traffic volumes anticipated on minor residential streets at lower densities, one family per net acre or less, occasional parked vehicles on the roadway would not likely constitute a serious hazard or inconvenience to the driver. For these reasons, the provision of a parking lane for traffic safety and driver convenience does not seem necessary.

On typical feeder streets, i.e., those which serve abutting properties and function as a collector for minor street traffic, the provision of two moving lanes and two parking lanes to insure ease of travel is recommended.[13]

The factors which affect turning and backing movements, and thus the standards for pavement width, are not affected by

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12. See footnote 11, p. 8, <u>Supra</u>.

13. N.C.T.S., <u>op</u>. <u>cit</u>., p. 19. "...no matter how adequate off-street parking facilities may be, there will be occasional curb parking, and desired freedom of movement cannot be achieved on a feeder street if drivers must weave to avoid such occasional parkers. Moreover, unless the feeder is considerably wider than the minor residential streets, it will not attract minor street traffic and serve its function as a collector."

density. Design of driveway aprons, minimum turning radius of vehicles, and other like considerations are determinent.[14]

Summary

The density of development, as it affects volume of traffic generated, does not call for varying standards for pavement width of moving lanes on minor residential streets. The continuity of feeder alignment and the relation of the feeders to activity centers may attract additional volumes of traffic. Both generated and attracted traffic, therefore, should be considered in determining potential volumes of traffic for feeder streets which, of course, vary with local conditions. For these reasons, the standards for pavement width of moving lanes on feeder streets are better related to volumes of traffic than the factor of density itself.

The need for parking lanes which affects standards for pavement width vary according to the density of development. On minor residential streets at densities of two families per net acre or more, the amount of area on the lot to accommodate off-street parking, and the incidence of temporary parking makes one parking lane most desirable to accommodate parking needs, and maintain two-directional traffic with a minimum of

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14. Ibid., p. 15. Not less than 26' of pavement width is recommended in order that a car may back out of a driveway when a car is parked opposite. However, proper design of driveway layout, and flared aprons should allow for proper backing maneuvers.

driver inconvenience. The provision of a parking lane on minor residential streets at densities of less than two families per net acre does not seem necessary. On typical feeder streets two moving lanes and two parking lanes are recommended to insure convenient traffic movement and the feeder's function as a collector.

Standards for pavement width which vary according to density are suggested as follows:

<u>Minor Residential Streets</u>

Density - Families per net acre	Moving Lanes	Parking Lanes	Total
7 - 2	two (18')	one (8')	(26')
1 - 0.5	two (18')	none	(18')

Standards and Requirements for Sidewalks

The installation of sidewalks on residential streets is necessary to insure safe and convenient pedestrian travel, and provide play space for children - roller skating, riding tricycles, and other like activities.[15] Of the factors which affect the function of sidewalks, the most significant in determining requirements for sidewalks are: amount of pedestrian traffic, and speed and volume of vehicular traffic.[16]

From the standpoint of safety, most authorities recommend that sidewalks are desirable where pedestrian traffic and street play by children are "appreciable".[17] The amount of pedestrian traffic and street play by children vary with the

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15. American Public Health Association, Planning The Neighborhood, (Chicago, Public Administration Service, 1948), p. 57. Also see N.C.T.S., op. cit., p. 24.

16. American Society of Planning Officials, Planning Advisory Service, Information Report No. 95 - Sidewalks in the Suburbs, (Chicago, ASPO, 1957), pp. 2-3.

17. N.C.T.S., op. cit., p. 24. "...good sidewalks should be provided on every residential street. It is unsafe, unreasonable, and often disagreeable to pedestrians to be forced to walk on the paved roadway. There may be places, as in estate-type developments, where a sidewalk only on one side, or even no sides can be justified, but this should be a very rare exception." Also see, A.S.P.O., Information Report No. 95, p. 2. "Unfortunately there is no good accident record available which would demonstrate the relation between child safety in areas with sidewalks and areas without sidewalks...,but sidewalks are desirable in all areas where pedestrian traffic is appreciable - this would apply to all residential developments."

density of development, and location of facilities which are pedestrian traffic generators.[18] At low densities, for example, one family per net acre, pedestrian traffic and the incidence of children at street play would be minimised for the following reasons: (a) lots are so spread out that visiting by neighbors may be less frequent than at higher densities, (b) lots are so large that play by children on the street is reduced because the larger lot size may be expected to accommodate such activities, and (c) distances from homes to shopping, schools, and other like activities are generally so great as to encourage use of the automobile. It seems reasonable to assume, therefore, that sidewalks will generally have a minimum value at low densities. At higher densities where we may expect increased pedestrian traffic, and a higher incidence of street play, the need for sidewalks seems considerable.

There is no empirical data with which one may determine numerical values of pedestrian volumes generated for the densities within the range chosen for study here. But we can expect pedestrian traffic to vary with the density of development; and an assumption regarding the relative conditions

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18. For the purposes of this discussion I have assumed a uniform family size of 3.6 people per family, and a uniform number of children per age group as follows: 0.19 children per dwelling unit of age group 2-5 years; 0.43 children of age group 6-13 years. The variable of locational factors which affect the incidence of pedestrian traffic generated is, for purposes of this discussion, assumed to be constant, and of no significant force and affect. Where pedestrian traffic generators lie within 1/4-1/2 mile walking distance, the value of sidewalks is enhanced. In actual situations both density and location are significant in varying sidewalk requirements.

which are likely to occur at different densities is as follows:

Density - Families per net acre	Conditions of Pedestrian Traffic and Street Play by Children
7-4	"maximum" conditions
3-2	"average" conditions
1-0.5	"minimum" conditions

On the basis of these assumptions, it would seem reasonable to vary the requirements for sidewalks according to the density of development.

Where sidewalk(s) cannot be justified on the basis of pedestrian traffic alone, potential hazards created by vehicular traffic conditions which may also be used in determining the need for sidewalks should be considered.[20]

One attempt has been made to determine the relationship between traffic volumes and sidewalk requirements, and to establish at what points traffic volume becomes critical:[21]

Speed m.p.h.	Traffic Volumes Vehicles per hour	Pedestrian Volume(day)	No. of Sidewalks required
30-50	30-100	150 (plus)	1
30-50	100 (plus)	100 (plus)	1
30-50	50-100	500 (plus)	2

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19. This writer strongly believes that the above assumptions reasonably approximate relative conditions of pedestrian traffic which are likely to occur at these densities. The assumptions are based, in part, on readings in the literature, and also are a result of observations which were made in developments. See Canton Planning Board, Rules and Regulations, 1958, p. 12; A.S.P.O., Information Report No. 95; Federal Housing Administration, Neighborhood Standards, Land Planning Bulletin No. 3, (Boston, FHA, 1957), data sheet 60 B & C.

20. A.S.P.O., Information Report No. 95, pp. 5-9.

21. Institute of Traffic Engineers, Traffic Engineering Handbook, (New Haven, ITE. 1950), p. 106.

On a minor residential street it was determined that traffic volumes are unlikely to reach or exceed 30 vehicles at peak hours.[22] This suggests, in light of the previous discussion, that the variable of traffic volume may be insufficient in itself to measure the need for sidewalks at conditions which are likely to occur in developments at these densities. On feeder streets, however, traffic volumes may reach 600 vehicles per hour.[23] Even under conditions of low pedestrian volumes at least one sidewalk should be installed for safety to pedestrians.

Standards for sidewalks, i.e., type of construction, width, and location vary with the requirements of sidewalk users and the amount of pedestrian traffic.[24]

Most authorities recommend smooth, well-paved, and easily drained sidewalks in order to encourage and sustain continued pedestrian use.[25] It is not reasonable, therefore, to vary this standard according to density.

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22. See page 6, Supra.

23. N.C.T.S., op. cit., p. 10.

24. A.S.P.O., Information Report No. 95, p. 10.

25. A.P.H.A., op. cit., p. 61. Pedestrians will tend to choose to walk on the roadway pavement if it is superior to the sidewalk.

The standards for width of sidewalk should vary according to the density of development which determines the character of pedestrian traffic, e.g., children on wheeled toys, mothers with baby carriages, etc., and the pedestrian volumes expected. Under "maximum" conditions of pedestrian traffic, the need is for more than the minimum sidewalk width to accommodate two footlanes of traffic.[26] However, the designation of numerical increments of width from the minimum of two footlanes in order to accommodate varying conditions of pedestrian traffic which are likely to occur does not seem justified on the basis of the data available at this time.[27]

The location of sidewalks, i.e., its set-back from the curb, will vary depending upon the width of planting strip in the typical design case. The standards for width of planting strip will be discussed in detail on the following pages.

Summary

The amount of pedestrian traffic generated, and the potential incidence of street play by children, which vary with density, were shown to be significant in determining the requirements for sidewalks.

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26. A.S.P.O., Information Report No. 95, p. 10.

27. Loc. cit.

Where pedestrian volumes are insufficient to vary requirements for sidewalks, speed and volume of vehicular traffic may be used to determine their need to insure the safety of pedestrians. This is especially significant on feeder streets where vehicular volumes may be critical.

Standards for the width of sidewalks are directly affected by the character and volume of pedestrian traffic which vary with the density of development.

Standards and requirements for sidewalks which vary according to density are suggested as follows:

Density - Families per net acre	Sidewalk Requirements minor streets	Sidewalk Requirements feeder streets
7-4	both sides	both sides
3-2	one side	both sides
1-0.5	none	one side

This writer further recommends that sidewalk width be reasonably varied from the minimum typical standard whenever density is "critical", e.g., in developments of five to seven families per net acre.

Standards and Requirements for Curbing

The installation of curbing along the edge of the paved roadway serves to: insure safety to pedestrians and children on a sidewalk,[28] control the movement of storm water along the gutter to catch basins and other storm drainage facilities, and protect the paved roadway from erosion.[29] Of the factors which affect the function of curbing, the most significant in determining the requirements for curbing are: the safety needs of pedestrians and children on the sidewalk, and the grade and horizontal alignment of streets.

The safety needs of pedestrians are related to requirements for curbing. The installation of properly designed curbs constitutes a substantial barrier to vehicles crossing from the roadway on to the planting strip or sidewalk.[30]

Given that curbing is desirable from a safety standpoint, it seems reasonable to postulate that the value of curbing for safety reasons is considerably enhanced where pedestrian and vehicular traffic conditions are appreciable. Where conditions of pedestrian and vehicular traffic justify the installation of sidewalks, curbing should be required for reasons of pedestrian safety.[31]

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28. N.C.T.S., op. cit., p. 15.

29. National Association of Home Builders, Home Builders Manuel for Land Development, (2nd ed., Washington, D.C., NAHB, 1958), pp. 105-106.

30. N.C.T.S., op. cit., p. 25. Also see, A.S.P.O., Information Report No. 95, pp. 12-13.

31. See section entitled, "Standards and Requirements for Sidewalks," pp. 16-17, Supra.

Requirements for sidewalks were shown to vary according to density which in turn determines, for the most part, conditions of pedestrian and vehicular traffic. It seems reasonable, therefore, that requirements for curbing can be varied according to density.

Standards and requirements for curbing in order to control the movement of storm water run-off along gutters to catch basins and other drainage facilities, vary with grade, alignment, gutter sections, and other like technical considerations,[32] which are not affected by density itself.

Summary

Pedestrian and vehicular traffic conditions, which vary with the density of development, call for varying requirements for curbing. Under conditions which justify the installation

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32. N.A.H.B., op. cit., p. 106. The grade of the road affects the velocity of storm water along the gutter at the edge of the pavement. Curbs are usually installed where grades exceed 5% in order to protect the pavement from erosion, and adequately control the storm water from washing away the loam berm of the grass strip. On curves, especially along the lower edge of a roadway that is superelevated, curbs are also recommended for the same reasons. Certain curb types are more desirable on grades; straight type curbs are recommended on grades in excess of 5%; roll type curbs may tend to "wash" and may not be able to channel and contain the storm-water. Further, sub-soil conditions preclude the use of certain type curbs, while under other conditions such curb types would be desirable, e.g., "set" granite curbs to the depth of gravel sub-surface are desirable when drainage conditions below the surface of the roadway create problems of road settling, and the like. Most of the authorities to whom I referred did not recommend the use of mountable or roll-type curbing, but prefer straight type curbing.

of sidewalks, curbing should be required to insure pedestrian safety. Requirements for curbing which vary according to density are suggested as follows:

Density - Families per net acre	Requirements for Curbing* minor streets	feeder streets
7-4	both sides	both sides
3-2	one side	both sides
1-0.5	none	one side

* Curbing is to be installed on that side of the street where a sidewalk is required.

Standards For Planting Strip

Proper standards for width of planting strip are necessary to provide an "isolation strip" between vehicular traffic on the roadway and pedestrians and children at play on the sidewalk,[33] provide for adequate space for lamp standards, hydrants, signs, and street trees outside of the sidewalk area, and provide space for snow removal from roadways and walks.[34] Of the factors which affect the function of planting strips, the most significant in determining the standards for width of planting strip are: the safety needs of pedestrians and children on sidewalks, and the space needs for those items outlined above.

The safety needs of pedestrians and children on a sidewalk are related to width of planting strip. Most authorities agree that a physical separation between the curb and the sidewalk by the use of a planting strip gives an added measure of safety and a feeling of security to the pedestrian, and acts as an isolation strip over which children are less likely to ride wheeled vehicles, or run into the street.[35] However, there is no general agreement among authorities as to what is considered a "safe" distance between pedestrians on

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33. N.C.T.S., op. cit., p. 25.

34. I have not considered the use of a planting strip here for purposes of storm drainage, e.g., open drainage swales. See section entitled, "Requirements for Storm Drainage."

35. N.C.T.S., op. cit., p. 25.

the sidewalk and moving vehicles in the roadway.[36] Empirical evidence to justify the choice of a numerical designation for this safety factor is not documented in the literature.[37]

This writer does strongly believe that there is a relationship between vehicular and pedestrian traffic conditions which vary with density, and the width of planting strip which should be required for reasons of safety and amenity, but there is lack of substantial evidence to support this.

The space needs for street furniture, street trees, and snow piling are not affected by differences in density of development itself.[38]

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36. Ibid. "The general consensus....was against the placement of a sidewalk next to the curb, but there was not complete agreement....the sidewalk should not be placed next to the curb anywhere except on a local residential street with straight curb - and even this had no strong support from the traffic standpoint. Most technicians favored the recommendation that sidewalks be set back at least 3', and if trees are planted in the strip, the set-back should be 7'."

37. A.S.P.O., Information Report No. 95.

38. A.S.P.O., Information Report No. 86 - Grading, Curb Cuts and Driveways: Street Trees, (Chicago, ASPO, 1956). The space needs for street furniture are minimal, and when street trees are excluded from the planting strip, most authorities suggest a minimum of 2'-3' for this purpose. Street trees in the planting strip do require at least a minimum of 7'-8'; trees should be located at least 3' from sidewalks and curbs. In regard to width of planting strip for snow piling purposes, variables such as width of pavement, sidewalks, quantity of snowfall, method of plowing and removal are critical. Density was shown to be significant in determining sidewalk requirements, roadway width which does affect the standards for planting strip in regard to snow piling. However, the variables of quantity of snowfall, whether walks are plowed toward the yards, and other like variables appear to be the major determinents.

Summary

Though a strong relationship was intuitively felt to exist between conditions of pedestrian and vehicular traffic, which vary with density and the width of planting strip required for pedestrian safety, there is a lack of substantial evidence to support this.

At this time evidence is insufficient to support the presentation of standards for the width of planting strip which vary according to density.

Standards for Width of Right-of-Way

The right-of-way is that width of street measured from property line to property line. Standards should provide sufficient width to accommodate space needs for cross-sectional design elements, and provide space for future street widenings. The factors which are most significant in determining the standards for width of right-of-way are: space needs of sidewalks, planting strips, curbs, gutters, paved roadway, and the possibility of future street widening.[39]

The space needs for many of the cross-sectional design elements were shown to vary according to density, e.g., pavement width, sidewalks, and curbs.

Other considerations for cross-sectional design elements are also affected by, but not wholly determined by density itself. In determining the space needs for planting strips, for example, tree planting between curb and sidewalks will vary the space needs for this design element considerably.[40]

Density, therefore, as well as other factors considered together should constitute the basis for determining the standards for width of right-of-way.

In line with the above discussion, this writer feels that the standards for width of right-of-way should be flexible; the

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39. The possibility of future street widenings should occur less frequently with proper advance planning for circulation facilities. The location, continuity of alignment, and rights-of-way for future streets should ideally be consistent with a comprehensive circulation plan for a community which recognises "local", as well as over-all community circulation needs.

40. See footnote 38, p. 22, *Supra*.

numerical standards, determined for the case in question.

Summary

The space needs for cross-sectional design elements, when taken together, constitute the standard for width of right-of-way. This should be determined for the given case in question.

Standards for Horizontal and Vertical Alignment of Streets

Standards for horizontal and vertical alignment of streets should be sufficient to insure safety and ease of vehicular travel by preventing sudden and sharp changes of alignment, which limit sight distance,[41] reduce traffic hazards,[42] and establish reasonable street grades for surface drainage.[43] The factors which act singly or in combination to determine standards for alignment are: volume and composition of traffic, use of abutting property and the extent of roadside hazards, design speed, and others.[44]

As the design of the road proceeds to detailed alignment and profile, the factor of design speed assumes the greatest importance, and acts to keep most of the other elements of road design in balance.[45]

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41. Lautner, op. cit., p. 75.

42. N.C.T.S., op. cit., p. 15.

43. Lautner, op. cit., p. 102. The grades for underground sewerage and drainage facilities are somewhat independent of the street grade itself; the layout for these facilities depends a great deal on the extent of existing facilities at their gradients. Though the gradients for underground utilities are not a critical determinent, they cannot be disregarded and must be examined in the light of local conditions by a competent engineer.

44. I.T.E., op. cit., p. 179.

45. A.A.S.H.O., op. cit., p. 79.. The design speed of a road affects, and is affected by other elements of road design. Sight distance, gradient, super-elevation, and horizontal curvature are directly related to, and vary appreciable with, design speed.

Though this writer strongly feels that design speeds and correspondingly standards for horizontal and vertical alignment should vary according to the density of development, the relationship between density and the most appropriate design that could be chosen is not well known.

This writer strongly suspects, however, that the choice of design speeds, and the corresponding standards for alignment should relate to density. It is known, for example, that drivers adjust their speeds to the physical limitations, and traffic on the road. We might reasonably expect, therefore, that the speeds that are adopted by drivers on residential streets at low densities would be higher than at densities where traffic volumes, extent of roadside hazards, and other like conditions are likely to be "appreciable". Further, drivers are more apt to adopt lower operating speeds in areas where such hazards are obvious than where there seems to be no apparent reason for it. It would seem reasonable, therefore, that a design speed for a feeder street of 25 m.p.h. in a development of one family per net acre, for example, would not seem sufficient to accommodate higher speeds of traffic that might reasonably be expected under these conditions.[46]

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46. N.C.T.S., op. cit., p. 4. This authority recommends a uniform design speed of 25 m.p.h. in accordance with the Uniform Vehicle Code. No variations in the standards for horizontal and vertical alignment are made for differences in density or the street types considered here.

Unfortunately, the affect of variations in density to these factors, in determining differences in design speed for varying conditions, is not well known.[47]

Summary

For all practical purposes, therefore, design speeds once chosen, may be used for varying standards for horizontal and vertical alignment.

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47. A.A.S.H.O., *op. cit.*, p. 79.

Standards for the Reservation of Land for Recreational Purposes

The reservation of land for recreational purposes in a subdivision development is necessary to insure adequate facilities to serve local needs for both active and passive recreational activities.[48] The factors which are significant in determining the standards for amount of land needed for recreational purposes are:[49] lot size, density and area of land being subdivided, location and capacity of existing recreational facilities, and conformance to Master Plan or Official Map.

Of the factors outlined above, lot size, which varies with density, is significant in determining the need for the reservation of land for recreational purposes.

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48. A.P.H.A., op. cit., p. 4. It was necessary to assume a uniform family size and a uniform number of children per play age group. The higher the number of people per family unit, or proportion of children per play age group, the greater the need for playground facilities and area required. Average family size assumed is 3.6 persons. Further, uniform number of children per age group is assumed by play age group as follows: 0.43 children per family unit of age group 6-13 years (for playgrounds). These figures are based on a full cross section of the population including single person households which are not likely to be found in single family residential subdivision developments; for any specific project, population figures must be checked for local age distribution and birth trends, and in relation to expected occupancy of the dwellings.

49. Lautner, op. cit., pp. 177-185.

The recreational activities that are possible on larger lots, one family per net acre, for example, seem sufficient for informal play, afford pleasant views of woodland, and provide open space for exposure to sunshine and healthful exercise - running, climbing trees, etc. At densities of seven families per net acre, for example, the opportunity for such activities is not possible to the same extent. Therefore, there is a strong need for planned recreation facilities at these higher densities.

For any given area, density also determines the potential load that recreational facilities will be expected to accommodate. For example, it was calculated that at densities of one family per net acre or less, the number of families within a 1/4 mile walking distance would not seem sufficient to justify the allocation of land for a playground facility.[50]

In determining the need for recreational facilities at different densities, the writer, for the most part, has generally followed the recommendations of the authorities. The amound of land to be reserved for recreational purposes per

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50. I assumed no neighborhood park facility at these densities. (See A.P.H.A., op. cit., pp. 47-48) Rough calculations were made based on various street pattern and block sizes, including a grid pattern of blocks 1120' x 530' assuming typical design case, i.e., streets are primary pedestrian circulation routes. Figures range from 110-125 families within the 1/4 mile walking distance. Also see footnote 51, p. 31, Supra.

dwelling unit vary according to density as follows:[51]

Density - Families per net acre	Playground Acres/1000 Total Pop.	Neighbor-hood Park Acres/1000	Total Acres/ 1000	Total Acres/ family
7-5	2.75	1.50	4.25	0.015
4-2	2.75	Not Required	2.75	0.010
1-0.5	Not Required	Not Required	none	none

The amount of land to be reserved for local recreational needs, therefore, can be easily calculated by multiplying the number of lots in the proposed development by the standard in acres per family specified for that density. The higher the density per given area of development, the greater the amount of land that is required for recreational purposes.

Proper standards are also necessary to insure that land reserved for recreational purposes will be of a character

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51. A.P.H.A., op. cit., pp. 47-49. In all cases a maximum walking distance is assumed at 1/4 mile, and uniform values in acres per 1000 total population for the recreational facilities based on the highest value presented by this authority have been used. No provisions for playlots are made in that these facilities are frequently unnecessary where private yards are sufficient for the play activities of age group in question, (pre-school children 2-5 years old). About 2.75 acres are recommended for a playground as the minimum desirable area which is sufficient to accommodate equipment and activity space for approximately 120 children (age group 6-13 years). Standards of 1.5 acre per 1000 people is accepted as minimum standard for neighborhood parks to accommodate local needs for passive recreational activity. A.P.H.A. specified no requirements for neighborhood parks in developments where the net acreage per lot was 1/4 of an acre (10,800 sq. ft.) or larger.

which is suitable for the proposed use, will properly relate to the surrounding development, and conform as closely as possible to the Master Plan or Official Map. These factors depend a great deal on the locality or site in question, and are not significantly affected by the density of development itself.[52]

Summary

The lot size for different densities is significant in determining the need for local recreational facilities. For any given area, density is also important in determining the potential load that local recreational facilities would be expected to accommodate. Thus, the amount of land to be reserved for recreational purposes, in acres per family unit, will vary according to the density of development.

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52. Lautner, op. cit., p. 180. Also see A.P.H.A., op. cit., pp. 48-49. Conditions of soil, drainage, topography, and other like considerations which are significant in determining standards for sites to be reserved for recreational purposes, vary considerably with the locality or site in question. Further, the location of proposed sites should conform as closely as possible to the Master Plan, and should be determined in part upon existing recreational sites and other like local factors.

Standards for land to be reserved for local recreational purposes which vary according to density are suggested as follows:

Density - Families per net acre	Land to be Reserved for Recreational Purposes
7-5	0.015 Acres/family
4-2	0.010 Acres/family
1-0.5	none

Requirements for Sanitary Sewerage

Sanitary sewerage to insure the proper removal and disposal of human excreta from a dwelling unit is necessary to maintain public health.[53] The factors which are most significant in determining the requirements for the type of system to be utilised are:[54] availability of the municipal system, feasibility of group system, and the physical characteristics of the site or locality in question, e.g., drainage, topography, source of water supply, and the size of lot necessary to obtain the proper layout of a disposal field for individual septic tanks.

The factor of lot size, which varies with the density of development, is significant, in part, in determining the requirements for the type of sanitary sewerage to be utilised, i.e., the point at which proper layout of disposal field for septic tanks is allowable. The sanitary engineer, with whom I consulted, recommended that approximately 20,000 sq. ft. is the minimum lot size suitable for the use of a septic tank to allow for a maximum of safety and continuity of

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53. Lautner, op. cit., p. 288. Generally, there are three methods for handling sanitary sewage from new residential developments, which are (a) the connection with a municipal system, (b) connection into a group system and treatment by a disposal plant on the site, (c) provisions of individual septic tanks, and treatment by leeching field and/or seepage pit on each lot.

54. See footnote 3, p. 3, Supra.

operation of this facility.[55]

Lot size alone, however, is not the sole factor in determining the use of individual septic tanks. The physical conditions of the site, e.g., water table, soil quality, potential hazards of flooding, and other like technical considerations may be critical in determining whether or not septic tanks can be used.[56]

It would not seem reasonable, therefore, to vary requirements for sanitary sewerage based on the density of development

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55. Interview with Mr. Thomas Rinaldo, Sanitary Engineer, Consultant to the Board of Health, Framingham, Massachusetts. The calculation of a minimum lot size of 20,000 square feet is based on the following assumptions. Critical perculation rates of 30 minutes, a sufficient area for a 100% relocation of a five-line absorption field, a septic tank capacity of 1000 gallons for a three bedroom home (also provides for automatic garbage and washing machines), a public or group system of water supply, and no flooding hazards. The minimum area for the absorption fields was calculated at 5000 square feet, and it was suggested that no more than 25% of the lot should be utilised for sewerage purposes, hence the minimum area of 20,000 square feet. Mr. Rinaldo further agreed that planning for critical conditions assured a reasonable margin of safety, and stated that the intermittent use of two disposal fields assured a continuity of operation of this system if properly maintained. Also see N.A.H.B., op. cit., p. 97.

56. N.A.H.B., op. cit., pp. 85-88. Soil of an impervious quality, e.g., tight clay, rock, prohibits the use of individual septic tanks if the perculation rates (the time it takes water to fall 1" at the maximum depth of absorption field) exceeds 30 minutes. A high water table or periodic flooding render the use of land for individual septic tanks undesirable; noxious odors, and hazards to health and safety may result. If private underground sources of water supply are utilised, special provisions to avoid contamination must be made.

itself, though this writer does not recommend the use of individual septic tanks on lots less than 20,000 square feet, given that other conditions are suitable for their use.

The availability of a public system, or the feasibility of a group system for sanitary sewerage depend on technical and/or other consideration which vary with the locality in question.[57]

Summary

Density, in part, does determine the point at which the proper layout of disposal field for septic tanks is allowable, though the physical conditions of a site may be critical in determining their use. Therefore, both lot size, and physical conditions determined by local survey, should be considered

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57. The availability of the existing public system includes the location in respect to the proposed development, the capacity of the system to accommodate the additional load, and the ability of the system to serve the area by gravity flow, or lift pump system. Availability also includes the willingness of the developer, community, or both in the extention of the existing system. Whether or not the public system should be extended depends upon what implications there are in regard to the future land use development of the over-all area of which the subdivision is a part. Ideally, the extention of the public system should be shown to secure substantially the objectives of proper and timely development of an area consistent with the communities interest for orderly growth, as set forth in a Master Plan, as it is developed and adopted by the Planning Board. Size of development may be a limiting factor in regard to whether or not a group system is feasible. There is a limiting size of development which would preclude the installation of a group system from the standpoint of costs. Further, unless maintenance and operation of a group system is integrally established at the outset, this system will be less satisfactory than if connection with the public system was required.

before septic tanks are installed. This author does not recommend the use of septic tanks on a lot size less than 20,000 square feet, given that other conditions are suitable for their use.

Whether a public system or a group system of sanitary sewerage can be utilised depends on a host of factors which vary with the locality in question, and which are not, for all practical purposes, significantly affected by the density of development itself.

Requirements for Water Supply

A proper system of water supply is necessary to provide safe and potable water delivered under pressure within a dwelling, and to insure an adequate rate-of-supply for fire protection needs. The factors which are significant in determining the requirements for the type of system to be utilised are:[58] fire protection needs, availability of the municipal system,[59] feasibility of a group system,[60] and physical conditions of the site for the use of wells on individual lots.[61]

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58. See footnote 3, p. 3, Supra.

59. The availability of a public system includes its location from the proposed development, the capacity of the system, and other considerations which vary with the locality or site in question. Where a public system lies within a reasonable distance from the development, and is of sufficient capacity to accommodate the additional load, connection with a public system of water is recommended. What is considered "reasonable distance" will vary with the willingness of the developer, the community, or both in extending the public system. Further, a community may control the rate and location of subdivision growth by its willingness or reluctance to extend utilities if connection with the public system is mandatory. Ideally, the problem of controlling rate and location of subdivision development should be worked out consistent with over-all community needs for orderly and efficient development as set-forth in a Master Plan, as it is developed and adopted by a planning board.

60. N.A.H.B., op. cit., p. 61. A group system for water supply should be considered if connection to a public system is not feasible. If an on-site group system is constructed, it should meet all the criteria in regard to quality and quantity of water for domestic and fire-protection uses as established for a public system, including integral provisions for maintenance and operation.

61. A.P.H.A., op. cit., pp. 14-15. Peculiar conditions of the site, e.g., hazards of flooding, water table, soil types, and others, may make the use of one type of system preferable to another, particularly for reasons of health, i.e., potential contamination, etc. Competent expert advice from a sanitary engineer and public health authority is absolutely necessary, for each condition will invariably be different depending on local conditions.

The density of development generally determines the relative spacing between houses, which affects fire protection needs. The rate-of-supply of water for fire protection needs significantly affects the type of system which should be utilised. Within the ranges of density chosen in this study, the consensus of all the authorities to whom this writer referred, recommended connection with a public system, or the installation of a group system, in order to assure a continuous rate-of-supply adequate for fire-fighting purposes.[62] The use of wells on individual lots for fire protection needs at these densities, is not recognised as suitable by these authorities.

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62. A.P.H.A., op. cit., p. 65. The system of water supply for fire protection needs in any area varies with spacing between dwelling, type of construction, availability and use of chemical fire-fighting apparatus, the presence of near-by water bodies for dual or mobile-type fire fighting systems, and the available hydrant pressures for "usual" fire fighting systems. I have assumed that the majority of new single family homes will continue to be built of materials which are relatively combustible, that chemical fire-fighting equipment is not likely to be used extensively, and that fire-fighting systems will continue to be dependent on an uninterrupted and sufficient rate-of-supply of water. Standards for public or group systems are based on a hydrant pressure of 50-60 lbs. per sq. in., or a rate of 250 gallons per minute for a minimum of two hours for fire-fighting purposes. This standard, rather than density of population served, is determinent in single family residential developments, for it far exceeds the rate of supply for other domestic water uses.

In the interest of public safety and the conservation of property, the use of a system for water supply, other than a public or group system, does not seem reasonable or desirable.

Summary

For developments within the ranges of density chosen, the use of public or group system of water supply to insure an adequate rate-of-supply for fire protection needs should be required for the protection of public safety, and the conservation of property. All the authorities to whom this writer referred did not recognise the use of wells on individual lots at these densities as being suitable for fire-fighting needs.

Requirements for Storm Drainage

Facilities to dispose of surface and storm water run-off should be adequate to insure that land be used without danger to health. The factors which are significant in determining the requirements for storm drainage are:[63] rate of rainfall, the area of the watershed of which the development is a part, and the percentage of imperviousness of the surface. Of the factors outlined above, the imperviousness of the surface of an area is considerably affected by density of development. Density measures the amount of land covered by buildings, streets, driveways, etc., to open area. We would expect that the more completely developed any given area is with buildings and pavement, the more elaborate would be the installation of facilities for storm water run-off.[64]

Density alone, however, is not the sole factor in determining the imperviousness of the surface. The imperviousness of the surface of a watershed which affects the quantity of storm water run-off is also dependent upon the quality of soil to absorb water, and the slope or topography of the site. These variables, including the factor of density, taken together constitute the basis for determining the factor of imperviousness, thus affecting in part, the requirements for

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63. See footnote 3, p. 3, Supra.

64. N.C.T.S., op. cit., p. 96.

storm drainage.

Other variables which are important in determining the requirements for storm drainage are dependent upon conditions of the locality or site in question, e.g., area of the watershed, rate of rainfall, and other like technical considerations.[65]

In line with the above discussion it does not seem operationally practical to vary requirements for storm drainage according to the density of development itself.

Summary

The complexity and extent of storm drainage facilities vary considerably with the locality or site in question. Differences in topography, soil quality, water table, area of the watershed, rate of rainfall, including the factor of density, should be considered together in determining the requirements for storm drainage.

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65. A.P.H.A., op. cit., pp. 13-14, and interview with Town Engineer, Framingham, Mass. The amount of run-off is calculated in the following way: $Q = A \cdot I \cdot R$, where "Q" equals the quantity of run-off, "A" equals the area of the entire watershed of which the subdivision is a part, "I" equals the percentage of imperviousness of the entire watershed; this includes a determination of the absorptive capacity of the soil, and slope, land coverage by impervious surfaces, including consideration of potential development of the watershed, "R" the maximum average rate of rainfall which may occur during the time of concentration as determined on a worst storm frequency of 5, 10, or 25 years. (The longer the time frequency, the greater the margin of safety in calculating the capacity of the system) The area of the watershed and potential development and rate of rainfall will vary with the locality or site in question, and must be determined by local survey.

SUMMARY AND CONCLUSIONS

In summarising the results of the study it was found that:

1. Certain of the selected standards and requirements can be varied according to density.

2. There are other standards and requirements where variation according to density is not operationally practical.

3. There were some instances where it was strongly suspected that standards and requirements could be varied according to density, but data was insufficient to support this.

4. There is a set of density ranges that can be established within each of which standards are constant, and among which some standards will vary.

The foregoing analysis has demonstrated conclusively that certain of the selected standards and requirements could be varied according to the density of development itself. This was most clearly demonstrated in those instances where density alone was shown to have a significant effect on one or more of the factors which determined the standards and requirements, and where definitive standards and requirements which properly reflected the relationship between density and those factors could be established, e.g., standards for pavement width, land to be reserved for recreational purposes, and requirements for sidewalks and curbing.

There are some standards and requirements where variation according to density alone is not operationally practical, e.g., standards for width of right-of-way, and requirements for storm drainage and sanitary sewerage. For these items, the variable of density was so interwoven with other variables, that density itself, for all practical purposes, could not be separated as the criterion upon which variations could be made. For example, the imperviousness of the surface of a watershed which affects the quantity of storm-water run-off is dependent upon quality of soil to absorb water, slope or topography of the site, and the density of development (driveways, roofs, pavements, etc.). These variables taken together constitute the basis for determining the factor of imperviousness, and thus affect, in part, the requirements for storm drainage facilities.

For standards and requirements of this nature, criteria other than density alone must be established as a basis for determining variations thereon.

There were some standards and requirements where it was strongly suspected that variation according to density could be made, but data was insufficient to support this. In these instances density was shown to have a significant effect on one or more of the factors which determined the standards and requirements, but definitive standards which properly reflected the relationship between density and those factors could not be established, e.g., standards for the width of sidewalks. In other instances, density was strongly suspected to effect those factors which determined the standards and requirements, but data to support this was insufficient, e.g., standards for width of planting strip, and standards for horizontal and vertical alignment.

Investigation further established that there is a set of density ranges within each of which standards are constant, and among which some standards vary. The set of density ranges, and the standards and requirements that vary according to these density ranges are as follows:

Item	Density-Families per Net Acre 0.5 - 1	2 - 3	4 - 7
Pavement Width minor streets	18'	26'	26'
Sidewalks			
minor streets	none	one side	both sides
feeder streets	one side	both sides	both sides
Curbing			
minor streets	none	one side	both sides
feeder streets	one side	both sides	both sides
Land for Recreational Use in Acres per Family	none	0.010 Acres	0.015 Acres

The implication of the findings above suggest to this writer that there are three distinct "development types" in respect to density, which in turn require varying improvements and facilities which are most appropriate for a given intensity of land use. On the basis of these findings, this writer suggests that the set of density ranges set forth could be used to classify subdivision developments into "density types", specified by lot area and frontage requirements to which varying standards and requirements could be related.[66] In this way standards and requirements under subdivision control regulations could be correlated with the appropriate lot area and frontage requirements under zoning districts.[67]

In conclusion, it is recommended that, in appropriate instances, standards and requirements which vary according to density be formulated. It is further recommended that developments be classified into density types, specified by lot area and frontage requirements to which such formulated standards and requirements could be related. Subdivision regulations which include these formulated standards and requirements in the manner prescribed above will provide, in the writer's opinion, a clear guide to planning boards for both mandatory and discretionary actions. Such regulations will further provide for the development of land more properly related to intensity of use.

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1. Mr. William E. Barbour, City Planner, Boston City Planning Board.

2. Mr. Allen Benjamin, City Planning Consultant, Wayland, Mass.

3. Mr. Walter Devine, Town Engineer, Brookline, Mass.

4. Mr. Donald Kirby, Mass. Dept. of Commerce, Division of Planning, Boston, Mass.

5. Mr. Richard E. Mackey, Town Engineer, Framingham, Mass.

6. Mr. Thomas Rinaldo, Sanitary Engineer and Consultant to Framingham Board of Health.

7. Mr. U. M. Schiavone, Town Engineer, Newton, Mass.