Transportation and Urban Form: A Case Study of the Des Moines Metropolitan Area

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It is well known that urban form is highly correlated with the evolution of transportation systems. In order to develop planning tools that are responsive to the complicated interaction between transportation and land use, it is helpful to identify the typical characteristics of the development of urban form. The relationship between transportation, land use and urban form is complicated by feedback relationships. Understanding the three-way dynamics between land supply, urban development and travel demand is a first step toward understanding these aspects in the transportation planning process. Using the Des Moines metropolitan area as a case study, this paper begins to examine and quantify some of these relationships. The purpose of this paper is to examine how urban form accommodates transportation systems and vice versa at a conceptual level. This is accomplished through a review of past studies on urban form and transportation from both design and transportation planning literature. The case study demonstrates the relationships between urban population density, travel pattern, residential and commercial distribution, using an interface between MapInfo and Tranplan. Following the characterization provided in the case study, suggestions for further strengthening of the relationship between land use and transportation in travel planning models are recommended. Key words: transportation, urban form, the Des Moines metropolitan area.

INTRODUCTION

It is well known that city development patterns are highly correlated with the evolution of transportation systems (*1*). In order to develop planning tools that are more responsive to the complicated interaction between transportation and land use, it is first necessary to identify the typical characteristics of the development of urban form (*2*). The relationship between transportation, land use and urban form is complicated by the fact that change in any one of these aspects will also result in changes in the other two. The ability to predict and display the three-way dynamics between the level of land supply, urban development and travel demand would be helpful to decision-makers (*3*). In this paper, a case study of the Des Moines metropolitan area is presented to demonstrate and shed light on some of these relationships.

The purpose of this paper is to examine how urban form accommodates transportation systems and vice versa at a conceptual level, and to contribute some additional understanding of the transportation and urban form literature. The historical development of the Des Moines area is reviewed to see how urban form is accommodated by transportation evolution, and the conventional transportation modeling process is reviewed to see how urban form is implied in the transportation modeling process. Seven spatial measurements are used to quantify urban form in Des Moines and its existing transportation network.

TRANSPORTATION AND URBAN FORM

The Historical Development of the Des Moines Area

A review of the historical development of Des Moines area is given to provide a pictorial description of how transportation and urban form have accommodated each other (*4*). Table 1 summarizes the different phases of Des Moines' development, its corresponding transportation systems and transportation eras. Des Moines, like other cities, benefited from both transportation modal evolution (from ferry to automobiles) and transportation network evolution. The transportation system can be considered an expression of urban spatial pattern during the historical development of the city.

The Conventional Transportation Modeling Process

Transportation models are computerized procedures for estimating changes in travel patterns in response to changes in development. The development of an open space into a shopping center, or changing demographics often require changes in the transportation network (*8*). Table 2 summarizes how urban form is implied in the conventional, sequential transportation modeling process of trip generation, trip distribution, modal split and traffic assignment (*9*).

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TABLE 1 Des Moines' Development Stages and Transportation Systems

Phases	Urban Development Characteristics	Transportation Systems (*4*,*5*)	Transportation Era (*6*,*7*)
1673 - 1838	No political entity; prairie land	Raft, ferry, horseback	Walking-Horsecar Era
1839 - 1857	More residential housing, predominant farm production	Stage (horse and wagon) or river	Walking-Horsecar Era
1858 - 1881	More social life, political byplay, increased population and housing	Horse-car, railroad, steamboats, dirt roads	Walking-Horsecar Era
1882 - 1910	Substantial urban development with increased population and housing, manufacturing, business and open space	Electric-trolley, railroads, recreation automobiles, paved roads	Walking-Horsecar Era Electric Streetcar Era
1911 - 1937	Substantial city sprawl, focusing on real estate, finance	Electric-trolley, railroads, more automobiles, better roads	Electric Streetcar Era Recreation Automobiles
1938 - 1947	Economic indicators went up, heavy investment on highway	Trackless-trolley, automobiles, bridges, highways	Recreation Automobiles
1948 - 1967	Urban renewal, more affordable and better housing, congestion	Diesel motor coach for transit, automobile, bridges, interstate highways, one-way streets	Freeway Era
1968 - 1978	City government closer to people, start comprehensive planning	Transit service deteriorating, increased automobiles use, airport, completion of highway system	Freeway Era
1979 - present	Continued urban sprawl, urban form becomes an issue with current growth scenario	I-235 becomes a priority; sustainable transportation system becomes an issue	Freeway Era

TABLE 2 Urban Form Is Implied in the Transportation Modeling Process

Transportation Modeling Process	Elements Implied in Modeling Process (*10*)	System Components in Urban Spatial Structure	Criteria for Urban Spatial Form (*11*)
Trip Generation	Land Use, Socio-economic, Demographic	Land use	Density pattern, homogeneity, concentricity
Trip Distribution	Travel time impedance, Personal preference, Socio-economic	Land use	Connectivity, density patterns and density gradient
Modal Split	Transportation policy, Auto ownership, Residential density, Income, Distance from CBD, Service	Land use, principles of urban structure, external determinants, the geographic extent and limits of the urban area	Density pattern, density gradient, sectorality
Traffic Assignment	Geometrics, Transportation network, Capacity of the roadway	Geographic extent and limits, the transportation network and its capacity	Directionality, connectivity

Seven Selected Spatial Measurements

Seven spatial criteria are presented here: homogeneity, directionality, connectivity, density pattern, density gradient, concentricity and sectorality (*11*) to measure the urban form of the Des Moines metropolitan area.

Homogeneity measures diversity of land uses or social areas. Density pattern reflects the shape and intensity of population density. Connectivity is used to demonstrate the roadway network.

Density gradient measures change in population density from the CBD of the City of Des Moines. Concentricity is defined as the degree to which uses and activities are organized zonally around the center. Sectorality is defined as the degree to which uses and activities are organized sectorally around the city center. In the Des Moines metropolitan area, population, housing and trips are highly concentrated at the central part of the metropolitan area. Center displacement and "the standard ellipse" are used to assess the directionality of the metropolitan area. Studies of the CBD and

TABLE 3 Seven Spatial Measurements and Des Moines Urban Form

Spatial Measurements	Urban Form Description
Homogeneity	Most commercial areas are located along major highways (I-235 and I-35), primary roads (14th St.) or at the junction of highways. High-density housing surrounds the downtown core. Industrial use is located along rivers and railroads.
Density pattern	High density population can be found in every city in the metropolitan area except the City of Cumming. Most of the population lives in the central part of the metropolitan area.
Connectivity	I-35 and I-80 run through the northern part of the metropolitan area. I-235 cuts through the heart of the metropolitan area. There are several east-west primary roads going through the entire area, while only 14th St. goes through the entire metropolitan area in the north-south direction.
Density gradient	The density gradient measures population density from the CBD of the City of Des Moines. It shows that the central part of the metropolitan area has the highest population density. Logarithmic regression seems more accurate than linear regression to reflect the overall density distribution from the CBD of the City of Des Moines.
Concentricity	Population and housing are highly concentrated in the central part of the metropolitan area. Work trips are also highly concentrated in the CBD of the City of Des Moines.
Directionality	The work trips are more west-east oriented than north-south. The difference between them is about 22%. The centers of the CBD of the City of Des Moines, the City of Des Moines itself and the entire metropolitan area are different. Development tends to shift to the geometric centers of a city or a region.
Sectorality	Sectorality is analyzed through CBD and corridor studies. The total population in the CBD and corridors is 15.5% of the total population in the metropolitan area, while the trip productions and attractions are 19.2% and 33.4% respectively. Activities are located in the CBD and along corridors.

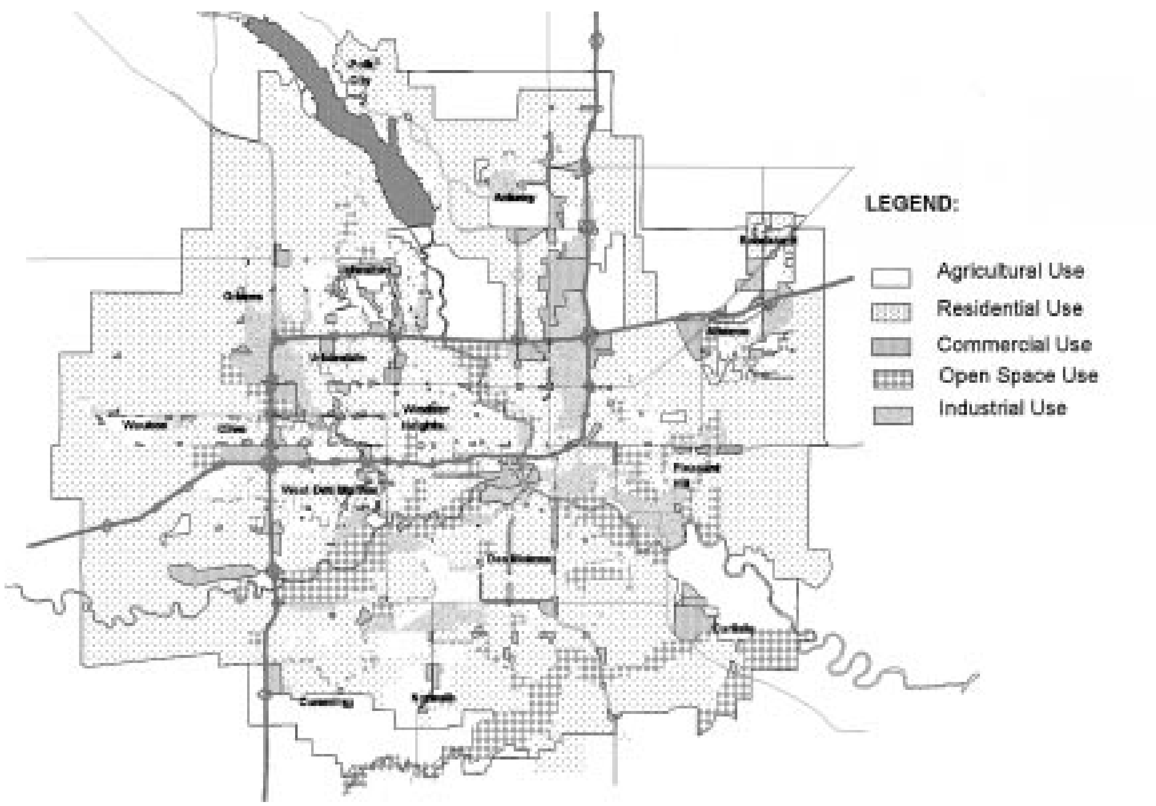

FIGURE 1 Different social areas and the transportation network in the Des Moines metropolitan area.

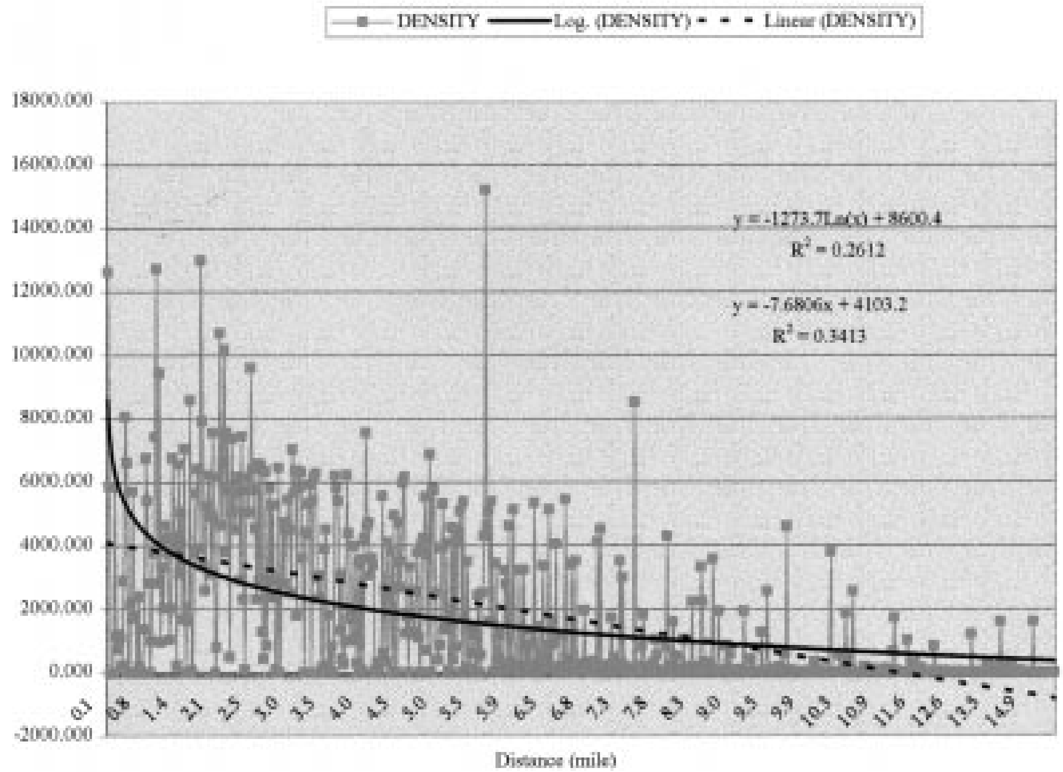

FIGURE 2 Population density gradient for the Des Moines metropolitan area.

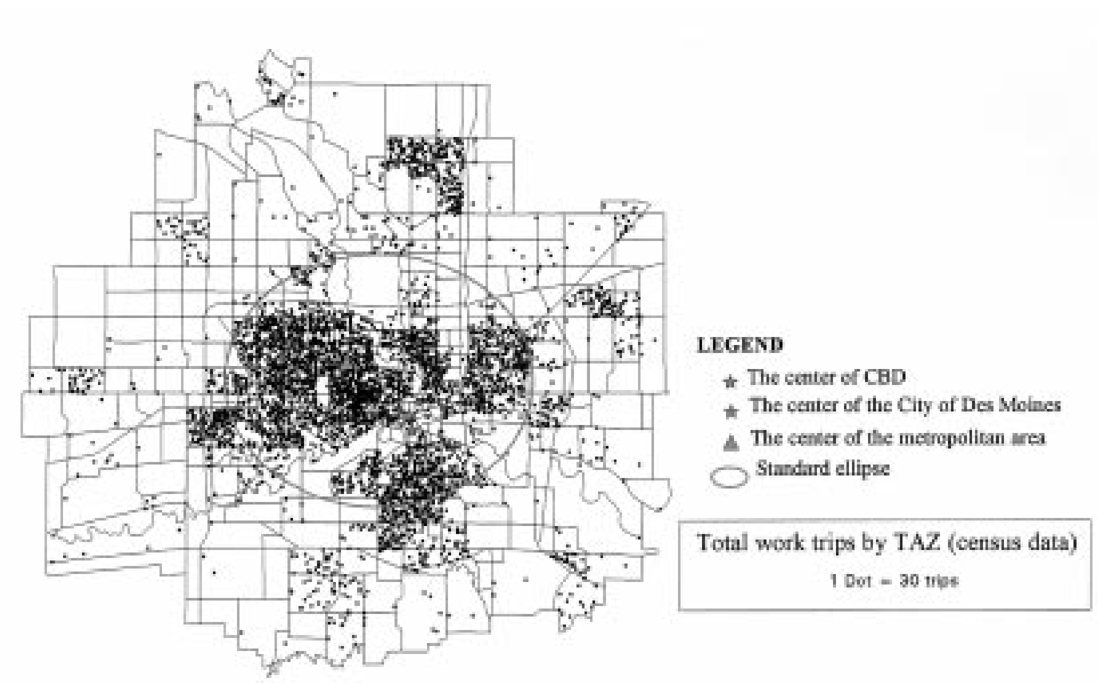

FIGURE 3 The standard ellipse and the centers of CDB, the City of Des Moines and the metropolitan area.

TABLE 4 The Number of Housing Units

Different Period	City of Des Moines	The Other 15 Cities
Housing built before 1939	26,718	2,279
Housing built in 1940s	10,032	1,556
Housing built in 1950s	15,026	5,144
Housing built in 1960s	11,718	9,345
Housing built in 1970s	12,312	14,682
Housing built in 1980s	7,553	14,336
Total number of housing units	83,289	47,352

TABLE 5 The Relative Locations of CBD, the City and Metropolitan Area Centers

Points	Coordinates (feet) X (feet)	Y(feet)	Distance from CBD Center (feet)	Distance from CBD Center (mile)	Direction From the CBD
CBD center	1966932.7	578564.0	-----	-----	-----
City center	1967512.8	575599.5	3020.72	0.57	South south east
Metro area center	1953970.0	589624.9	17040.40	3.23	Northwest

TABLE 6 The Summarized Results of the CBD and Corridor Study

Study Area	Land Use Description	Population	Trip Productions	Trip Attractions
CBD	General commercial uses	3,347 (0.94%)	57,493 (4.9%)	202,563 (15.7%)
E14th St. Corridor	Mixed uses with residential, commercial and open space uses	12,558 (3.54%)	35,994 (3.1%)	32,161 (2.5%)
Intersection I-235 and I-35 to intersection I-235 and NE 14th St.	Mixed residential uses with commercial uses	29,180 (8.2%)	102,709 (8.7%)	162,688 (12.6%)
Intersection I-235 and NE 14th St. to intersection I-235 and I-35	Mixed uses with more industrial uses	9,902 (2.8%)	29,701 (2.5%)	32,897 (2.6%)
Total Percentage		15.48%	19.2%	33.4%

corridor are used to examine the sectorality of the metropolitan area. Table 3 summarizes the results of the urban form of the Des Moines metropolitan area using these seven measurements.

Figure 1 shows different social areas and the transportation network in the Des Moines metropolitan area. Figure 2 shows the population density gradient. Figure 3 shows the center displacement and standard ellipse. Table 4 provides data on the housing units in the City of Des Moines and the other fifteen cities of the metropolitan area. Table 5 shows the relative locations of the centers of the CBD, the City of Des Moines and the metropolitan area. Table 6 shows the summarized results of the CBD and corridor study.

RESULTS

From the historical review of the development of the Des Moines area, the conventional transportation modeling process, and the seven spatial measurements, the results can be summarized as following:

1. The population density gradient shows that the central part of the Des Moines metropolitan area has the highest population density. Even though some other metropolitan area cities have been growing rapidly, they have not influenced the central city function of the City of Des Moines. The City of Des Moines is still the focal point for employment (approximately 60,000 employees per day in downtown) and population in the metropolitan area. Des Moines is the civic and cultural capital of the metropolitan area. The other cities are chiefly bedroom communities, even though they are beginning to show significant commercial and retail development. This development largely follows interstate highway development along I-235, I-80 and I-35. Some of the outlying cities may develop into special function cities, but are likely to retain the status of "satellites" of the City of Des Moines. The urban pattern of the Des Moines metropolitan area is radial in terms of trip attractions.

2. The location of the CBD of the City of Des Moines was largely influenced by the Raccoon River and the Des Moines River. Development in the City of Des Moines has since shifted southward. Within the metropolitan area, new developments are located northwest of the geometric center of the metropolitan area, which is close to the cities of Urbandale, Clive, West Des Moines and Windsor Heights. It is assumed that new developments tend to shift to the geometric center of a city or a region to overcome the friction of distance or space. People tend to make tradeoffs between transportation costs and land values. It is suggested that when examining the development trend for a city or a region, the geometric center or its vicinity may be the first measure that should be considered.
3. Based on census data, bicycle trips comprise only 0.2% of total work trips while walk trips make up 3.2% and bus trips are 2.9%. Future urban design could consider more use of these modes to make Des Moines more walkable and more bicycle and transit friendly.

RECOMMENDATIONS FOR FUTURE STUDY

When the urban form of one area was examined in this paper, no consideration was given to the organizational level, policy or decision-making levels of urban form. As both transportation planning and urban form changes are dynamic processes (*12*), the following items are recommended to better understand the relationship between transportation and urban form.

1. Explore the use of measures which explicitly account for urban form into transportation models, e.g, if a logit model is used for modal split, can say spatial measurements of the standard ellipse be applied to better calibrate the model?
2. Examine different transportation modes for effects on urban form.
3. Measure sewers, water and utility lines as determinants of urban form.
4. Examining the influence of zoning ordinances, building codes, other local policies, and national transportation policies that may shape urban form and the transportation network,
5. Assess the importance of life style as a determinant of urban form.
6. Measure more cities with different urban patterns and cities of different sizes to determine the statistical relationship between density gradient, urban pattern and transportation networks.

Transportation is surely not the only determinant shaping urban form. Other factors like those listed above are sometimes critical. However, realizing that not all transportation networks and investments are rational, truly understanding the relationship between transportation and urban form helps us make more rational decisions. The purposes of research on transportation and urban form are to provide better transportation networks and make more efficient investments on the existing network, to provide the residents a better place to live and work, and to make a more livable and sustainable city based on the existing transportation network.

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