after case (an increase in correct responses from 84 to 91 percent). No significant differences were found in the responses to question 2 in either city; thus the hypothesis that DS would be better understood as a clearance display was not sustained. As in experiment 1, the differences between cities were great at the experiment 2 sites. Compliance in Phoenix was nearly twice as high as that in Buffalo. The pedestrian understanding of signal indications also remained higher in Phoenix than in Buffalo.

Experiment 3: FW Versus Steady W

The results of experiment 3 are given in Table 3. As given in that table, a number of differences were found in the Buffalo behavioral data, whereas no significant differences were found in the Phoenix behavioral data. All of the differences in the Buffalo data favored the before (FW) case. The most significant results were that hesitations, vehicle hazards, and turning vehicle conflicts were reduced by 13, 6, and 4 percent respectively.

Significant differences were also apparent in the compliance data. As in experiment 1, the differences in pedestrians leaving the curb on the W indication were offsetting. In Buffalo, the before case was favored (compliance decreased 19 percent) and in Phoenix the after case was favored (compliance increased 8 percent). The same trends held when data from both sites in each city were combined. Compliance at these sites ranged from 21 to 40 and from 78 to 93 percent in Buffalo and Phoenix respectively. The proportion of pedestrians leaving the curb during the clearance indication (FDW) was not expected to change because the indication was the same in both the before and after cases. This expectation held true except at one site in Phoenix where a difference at the 0.05 level was found.

The most significant finding in this experiment was from the understanding data. Of the 400 pedestrians surveyed, only 2.5 percent understood the intended meaning of FW and steady W. Less than half of the pedestrians in both cities said that they would expect vehicles to be turning into the crosswalk during the W interval, even though turning vehicles in both cities made up one-fourth of the total traffic passing through the intersection when all turns were permitted. As mentioned earlier, turning vehicle conflicts dropped in Buffalo (4.0 to 0.4 percent) and remained the same for both the before and after cases in Phoenix (approximately 16 percent).

The trends in compliance differences between cities remained consistent with the trends in experiments 1 and 2. The behavioral differences found in Buffalo are not easily explained. The before and after sequence was reversed in Buffalo for this experiment, but there was a 2-month acclimation period to reduce or eliminate the novelty effect. There was no novelty effect apparent in the behavioral data for the other two experiments, and they were conducted simultaneously with this experiment.

CONCLUSIONS

1. A steady DW clearance display appears to have the same effectiveness as an FDW clearance display. There is not sufficient evidence to say that a steady clearance is better than a flashing clearance.
2. The DS message offers little or no improvement over the current DW message.
3. FW is not an effective means of warning pedestrians about turning vehicles.
4. Based on pedestrians' stated expectancy in regard to TVs, there is a need to make pedestrians more aware of TVs.
5. Pedestrians' observance of pedestrian signals varies somewhat from intersection to intersection and greatly from city to city.
6. The pedestrian behaviors used may be sensitive enough to reflect the responses of pedestrians to the subtle changes made in these experiments.

ACKNOWLEDGMENT

The conclusions stated here are mine and do not necessarily reflect the opinions of the Federal Highway Administration or the U.S. Department of Transportation.

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Abridgment

A Method for Estimating Pedestrian Volume in a Central Business District

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In the past decade, significant efforts have been directed toward improving the accessibility and revitalization of the central business district (CBD) in many large metropolitan areas. The ingenious concepts that emerged have been used to achieve economic goals as well as to satisfy the demand for CBD accessibility in many urban transportation developments. In spite of these successful developments, the most vital element of urban transportation, namely pedestrian movement, has been treated incomprehensively in many transportation studies. The importance of pedestrian circulation in the CBD area has not been recognized even though transportation by foot is the only efficient means of internal circulation for many short trips in the heart of the downtown area.

The innovative design and construction of pedestrian facilities or planning of such facilities requires a comprehensive knowledge of pedestrian traffic flow and behavior of pedestrian circulation in the CBD area. If the pedestrian facilities are planned to be built on vague assumptions and inadequate technical documentation, then the demand for such facilities will not be estimated accurately. Underestimation of pedestrian flow will lead to poor design in urban areas and the creation of discomfort among the users. On the other hand, if the facility is built on the basis of a highly overestimated pedestrian demand, then the funds used are wasted because they could have been used for other purposeful urban projects. Based on this rationale, scientific methods are vital to forecast the pedestrian volume in urban areas.

The primary purpose of this study was to develop a simple quantitative model that could be used by various planning and engineering staff of an urban government for predicting the pedestrian volume from land use data in the core of the CBD. The study design placed a special emphasis on the selection of variables that could be quantified and obtained without difficulty from the existing data bank of a city.

BACKGROUND

A limited number of studies have attempted to develop models for determining pedestrian volume in CBD areas. One of the studies related to this research has been conducted by Pushkarev and Zupan (1) in midtown Manhattan. The technique of regression analysis was used to establish a relation between instantaneous numbers of pedestrians on a street (dependent variable) and walkways, office space, retail stores, and restaurants (independent variables). The distance from the nearest transit station, an additional independent variable, was used in this study to represent the geographical distribution of opportunities for making trips. The data for this study were collected by aerial photography. However, one disadvantage of this technique was that counts could not include pedestrians walking through covered areas or areas concealed from view.

There are several problems involved in this study that deserve some attention. First, the study does not establish a direct relation between pedestrian volume and land use data. Second, the collection of data for geographical distribution and walkways many not be a simple task in many cases. Third, the cost of using aerial photography for pedestrian data and for the other two independent variables previously mentioned is generally beyond the financial capability of many cities. Although the study is of significance in the understanding of pedestrian circulation in the CBD area, it does not lend itself as a practical tool that could normally be used at a city level.

The conventional gravity model technique is applied to forecast pedestrian volume in the Toronto area. The study reported by Ness and others (2) employed gravity models to develop predictive tools for the journey to work and lunch-hour pedestrian circulation demands in the CBD area. The prediction model for pedestrian volume for the journey to work was developed relative to the location of transportation terminals and offices by dividing the CBD area into office zones. Pedestrian links were coded for CBD, depending on street configuration and office centroids. According to the study (2), "The inputs to the gravity model were the generation and attraction rates of office and transportation zone, a family of friction factors, and a set of minimum-path walking trees from all office centroids to all transportation zones." Similarly, the gravity model was used for the noon-hour circulation. Since the attraction rate was unknown, the minimum path was not calibrated by a usual approach. The calibration was completed on the basis of walking time, waiting time at intersections, street attractiveness, and a turn penalty. The simulation techniques were employed for the latter part of this study. The study will probably provide an accurate prediction of pedestrian circulation; however, the technique is difficult and the cost involved is high.

Haas and Morrall (3) have conducted a survey of pedestrian tunnels between all major buildings and parking lots of Carleton University, Ottawa, Canada. The objective was to develop a pedestrian demand model for future design criteria. Data had been collected by an origin-destination questionnaire survey. Screen-line counts and walking time-distance surveys were made for the calibration of the model. Screen-line counts were taken at the peak hour for all links. According to this study, "The walking time-distance measurements were obtained by using a floating pedestrian technique, similar to the floating car method often used in conventional traffic studies." The peak hour for the design was determined from the schedule of university classes. Trips were assigned to the network system (considering interzonal transfers) by a computer assignment program from the results of this survey.

LAND USE VARIABLES

Previous studies have shown that the relation between pedestrian traffic and influencing variables can be best studied by quantitative analysis. It is important to choose those variables that could be quantifiable and readily obtainable for the study. Thus, the following variables were chosen.

1. Commercial space (x_1) refers to the spaces used for retail stores, shopping areas, inns, restaurants, and other similar commercial activities that take place in the CBD area.
2. Office space (x_2) refers to the spaces used for governmental offices, professional offices, banks, and other financial institutions located in the study area.
3. Cultural and entertainment space (x_3) refers to the spaces associated with museums, historical sites, theaters, parks, educational institutions, and other similar activities located in the CBD.
4. Manufacturing space (x_4) refers to all spaces used for small-scale industries in the CBD area.
5. Residential space (x_5) refers to all spaces used for residential purposes in the study area.
6. Parking space (x_6) refers to parking spaces in the CBD area of the city and includes all parking lots and multistory parking garages used for parking purposes.
7. Vacant space (x_7) refers to the spaces that are allocated for some activity but were not used at the time of the land use survey and includes vacant spaces in the buildings and vacant lots found in each block.
8. Storage and maintenance space (x_8) refers to the spaces used for storage and maintenance purposes.

The variables described above are the independent variables, and the pedestrian volume per hour per block was the dependent variable used for developing the proposed models.

DATA COLLECTION

The pedestrian survey was conducted during the summers of 1971 through 1973 by field observers stationed at each midblock location within the defined area of study. The study area was divided into several numbers of loops of varying size, and each loop contained several blocks that were assigned to an observer. The procedure required that each observer count pedestrians in each loop for a period of 1 h at intervals of 6-min counts for each midblock station. Thus, the observer stationed at the midblock of a street counted the number of pedestrians who used the sidewalk in two directions for 6 min. After completing the 6-min count, the observer moved to the next station to continue the counting process. The loops were designed in such a manner that normally an observer could cover all stations in a loop within 1 h, which included the time it took the observer to relocate from one station to another. If the coverage of stations in a loop took an observer less than 1 h, the observer was instructed not to initiate a new count until the completion of a full hour. Manual mechanical counters were used in this study, and the survey was conducted between 6:00 a.m. and 6:00 p.m. during weekdays.

The pedestrian volumes for each sidewalk were derived from the data that were compiled by field measurement. The pedestrian volumes per hour were derived and expanded from the 6-min counts. For example, the pedestrian volume at the noon hour was obtained by multiplying the 6-min counts by a factor of 10. Likewise, the average volume per hour for each sidewalk was computed by dividing the total observed volumes per hour by the total survey time.

The land use data for this study were collected from the files of the Milwaukee Department of City Development. The department retains current detailed data on various aspects of land use that were suitable for the purpose of this study.

FORMULATION OF MODELS

A stepwise regression technique was used to discriminate and enter into the model the most significant land use variables that influenced the pedestrian volume. The computer enters variables in single steps from best to worst provided that they meet the preestablished statistical criteria. The variable that explains the greatest amount of variance in the dependent variable will enter first, and the variable that explains the greatest amount of variance in conjunction with the first variable will enter second. In other words, the variable that explains the greatest amount of variance unexplained by the variables already in the equation enters the equation in each step. This process continues until all variables with significant F-values are in the equation.

The statistical criterion used in developing the models was based on an F-level of significance of 0.05 for a variable to be included or excluded from the models.

Several potential models, linear and nonlinear, were applied to the data before the final models were selected. Since the noon hour was considered the peak pedestrian circulation period, the pedestrian volume during this period and the associated land use data were analyzed separately by the use of potential models. Similarly, the average pedestrian volume per hour and associated land use data were also applied to the potential models. This grouping was used to investigate the significance of noon-hour pedestrian circulation for the development and selection of the final model. Thus, two sets of equations were developed for each category and the best model was selected from each group. For this analysis, the final models for noon-hour pedestrian volume (model 1) and average pedestrian volume per hour (model 2) are shown below in Equations 1 and 2 respectively:

$$\ln \hat{Y} = 5.128 + 0.000\,004\,03\,x_1 + 0.000\,001\,99\,x_2 + 0.053\,8\,\ln x_3 + 0.056\,0\,\ln x_7 + 0.038\,9\,\ln x_8 \quad (1)$$

$$\ln \hat{Y} = 5.159 + 0.000\,003\,57\,x_1 + 0.000\,001\,90\,x_2 + 0.032\,2\,\ln x_3 + 0.034\,2\,\ln x_5 + 0.038\,2\,\ln x_7 + 0.035\,9\,\ln x_8 \quad (2)$$

where R = 0.739 and 0.764 and S_e = 0.726 and 0.568 for Equations 1 and 2 respectively.

EVALUATION OF MODELS

The statistical evaluation of these two models indicated that the models selected were good predictors of pedestrian volume and will provide relatively accurate results. The coefficient of multiple determination showed that approximately 60 percent of the variation in pedestrian volume is explained by land use variables. Further examination of Equations 1 and 2 indicates that the significant independent variables in both models are identical except for the residential land use variable (x_5) that was included in model 2. Also, the coefficient of correlation and the standard error of estimate displayed by each model are similar.

The coefficients of correlation derived for the models were statistically tested by comparing them to the critical values obtained from the statistical handbook (4) at the 0.01 level of significance. The critical values were 0.439 and 0.444 for models 1 and 2 respectively. Thus, the correlation coefficients were found to be highly significant for both models.

Further investigations were made to determine how the derived models compared in accuracy and what percentage of error should be expected to result if the models were used for prediction purposes. Since the models predict only total pedestrian volume for the entire block, a method was employed to compute the pedestrian volume for each sidewalk of the blocks. This approach was based on the ratio concept, and it was assumed that the current ratio of pedestrian volume on each side of the block to its total pedestrian volume will remain relatively stable through the years. Hence, the percentage of error for the entire block and each sidewalk of the block was computed by comparing the observed values to those calculated from the models. The results are given in Table 1. The typical blocks were chosen to provide a representative sample of volume variation for each condition previously mentioned. Generally, the percentage of error for model 2 is lower than that for model 1. Although model 2 has similar statistical characteristics and a fewer number of variables than model 1, the latter model produces errors that are somewhat lower, and thus model 1 would be the more suitable model to use for prediction purposes.

APPLICATION OF MODELS

The models developed during the conduct of this study have various practical applications in traffic engineering, transportation planning, and the design of pedestrian walkways in urban areas. Since the data required for these models can be collected simply and without high

Table 1. Percentages of error for observed and estimated pedestrian volumes on block sides and on total block.

		Side 1			Side 2			Side 3			Side 4			Total		
Model	Block	Observed	Estimated	Error	Observed	Estimated	Error	Observed	Estimated	Error	Observed	Estimated	Error	Observed	Estimated	Error
1	8	1180	857	-27.4	130	95	-26.9	60	44	-26.7	20	15	-25.0	1390	1011	-27.3
	11	3550	2519	-29.1	240	171	-28.8	200	142	-29.0	160	114	-28.8	4150	2946	-29.0
	96	40	42	+4.8	100	105	+4.8	20	21	+4.8	0	0	–	160	168	+4.8
	148	140	86	-38.6	10	6	-40.0	180	110	-38.9	150	92	-38.7	480	294	-38.8
	127	130	219	+40.6	80	135	+40.7	90	151	+40.4	70	118	+40.7	370	623	+40.6
2	8	843	661	-21.5	134	105	-21.6	40	31	-22.5	89	69	-22.5	1106	866	-21.6
	11	1768	1451	-17.9	283	233	-17.7	157	128	-18.5	159	130	-18.2	2367	1942	-17.9
	96	28	31	+9.7	47	53	+11.3	34	38	+10.5	46	52	+11.5	155	174	+10.9
	148	0	0	–	44	47	+6.4	118	127	+7.1	0	0	–	162	174	+6.9
	127	141	216	+34.7	43	66	+34.9	104	159	+34.6	106	162	+34.6	394	603	+34.8

Table 2. Example data for a 1990 forecast of pedestrian volumes on each sidewalk of a rectangular block.

Sidewalk	Existing (V)	Ratio (r)	Pedestrians per Hour ($\hat{Y}$)	Estimated ($\hat{V}$)
V_1	70	0.1186	734	87
V_2	240	0.4068	734	299
V_3	120	0.2034	734	149
V_4	160	0.2712	734	199

cost, the models have significant values in the field of transportation engineering. The following example of an application of the models in practice is presented to show the use of the derived models.

For example, consider a rectangular block that is located in the CBD area and has an existing pedestrian volume (pedestrians per hour) on each sidewalk as given in Table 2. The 1990 forecast of land use within the block is as follows:

Use	Amount (m^2)	Use	Amount (m^2)
x_1	3251.6	x_5	1207.7
x_2	3948.4	x_7	1022.0
x_3	929.0	x_8	1394.0

The average pedestrian volume per hour in 1990 ($\hat{Y}$) can be obtained by using Equation 2. Therefore, $\text{Ln } \hat{Y} = 6.599$ and $\hat{Y} = 734$.

The estimated volume can be distributed to each sidewalk of the block by the ratios (r) derived by dividing the total volume (V_t) of 590 pedestrians by the volumes on each sidewalk (V_1, V_2, V_3, and V_4). These ratios are also given in Table 2. Thus, the 1990 pedestrian volumes per hour ($\hat{V}$) for each sidewalk are obtained by the following equation and the values are given in Table 2.

$$\hat{V} = r(\hat{Y}) \tag{3}$$

These volumes may be used for planning, design, or evaluating the sidewalk level of service in the CBD area. Obviously, the models could be used for a variety of purposes in studying and planning the pedestrian circulation in the core of downtown.

LIMITATIONS OF MODELS

The data for this study were gathered in the CBD of Milwaukee, which is unique in its urban formation compared with other U.S. cities. This city is considered medium-sized and is an automobile-oriented urban community with a reasonable supply of parking space at a relatively moderate cost. The primary transit system currently in operation is a bus system that serves the metropolitan area of Milwaukee, and no major transit terminal exists in the CBD area except for the conventional bus stops. Thus, the models developed in this study represent the characteristics of the urban CBD in Milwaukee and its land use patterns in the CBD in relation to the pedestrian flow. These factors may be different for other cities.

Geographical factors are also important items that should be considered in the development and use of these models. Each region comprises groups of people who have characteristics, life-styles, and land use patterns that may be completely different from those of the CBD in Milwaukee. Thus, for those areas where the transit system and walking are a common form of transportation other variables may warrant consideration. The regions with mild climates and an elderly population will have a high pedestrian flow with different pedestrian characteristics and generations.

The models developed here contain terms with a natural logarithm of land use variables that may assume a zero value for certain blocks. This condition should not pose any difficulty in the computation process of the models. Since a zero value for any variable implies that the specific land use variable would not contribute to any flow of pedestrians, the value of unity should be used to avoid undefined terms, and, in the meantime, eliminate the effect of the variable from the model.

Last, the temporal nature of the regression model should be acknowledged for the purpose of clarification. The variables used in the development of these models may change periodically by urban renewal, change in allocation of space for different activities, and catastrophical events such as fire and earthquake. Therefore, the models should be updated and modified to preserve accuracy and stability in the estimation process.

CONCLUSIONS

The analysis of pedestrian volume and land use data produced two simple pedestrian-forecasting models for the CBD area. The models developed have significant advantages in terms of the data collection method and use of the models in practice. The data collection procedure employed for this study is less sophisticated than other collection procedures, but it is economically feasible and provides for reasonably accurate inputs for use in the models. The land use data needed for forecasting purposes can be obtained from city planning agencies without significant difficulty or cost in many U.S. cities.

The models have a wide range of applications in the field of transportation engineering such as planning, traffic engineering, and design of pedestrian facilities. The application of the models in practice was demonstrated by an example problem in this paper. The models were tested statistically, and there were no reasons to believe that the models would not provide reasonably accurate results. However, the models developed were based on the data collected in Milwaukee, which is a medium-sized city. The walking habits, degree of transit usage, composition of land use, and other factors may generate a different format of pedestrian models in other cities. Nevertheless, the models should provide a reasonably accurate forecast in CBDs of other cities that have synoptic characteristics.

Further research is needed to develop and study similar models for other cities and low-density areas. A possible approach would be to collect comprehensive and nationwide data that can be used to develop models for various classifications (low and high-density areas and small and large cities) in which the accuracy and validity of each model can be determined and compared with certainty. The results of this type of research may then provide a set or a unified model that may be used under various geographical and land use conditions for the estimation of pedestrian volumes.

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Abridgment

Accident Data Base for Urban Pedestrians

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The transportation safety community has been aware of the extent of the national pedestrian accident problem for many years. There are approximately 400 000 injuries and nearly 10 000 fatalities annually. The U.S. Department of Transportation became actively involved in determining the nature of the problem in 1969, when it funded a project to investigate urban pedestrian accidents. This project (1) identified the recurring accident patterns or accident types involved in urban pedestrian accidents. Since that time, similar research efforts have successfully identified the recurring behavioral antecedents in rural and suburban (2) as well as freeway pedestrian accidents (3).

The accident typology is the basis for developing countermeasures that are designed to affect the behavioral antecedents of the various accident types. A previous report (4) described the establishment of a pedestrian accident data system in several cities. The information in the regular police report was combined with information provided on a special supplementary form so that a type could be established for each accident. The resulting data base is used to evaluate the effectiveness of various countermeasures that reduce the occurrence of specific accident types in a pre- and post-experimental-control paradigm.

The purpose of this paper is to provide a profile of the accident experience; it is not intended to be analytical.

METHODOLOGICAL PROCEDURES

Each type of target accident has associated predisposing and precipitating factors. The effectiveness of a given countermeasure can be evaluated by ascertaining whether the reported accidents could be target types for that countermeasure. Thus, a number of items required for the pedestrian accident data were developed to determine the types of accidents that occur. These items included a combination of items already on the police accident report form and certain additional items needed to determine each accident type. Figure 1 shows the list of required data items formatted as a master coding form.

The police accident report forms in each city were analyzed to see which required data items were routinely collected. Thus, it was possible to identify the additional items to be collected in a supplementary form. Figure 2 is a typical supplementary data collection form that was used by one of the seven cities in the study.

Intrinsic in the design of the data items was the con-