ANALYZE FACTORS AFFECTING STUDENTS' TRAVEL MODES USING MULTI-PERSPECTIVES DIGNOSIS APPROACH

Huaguo Zhou, Ph.D., P.E.
Assistant Professor
Department of Civil Engineering, Southern Illinois University Edwardsville
Edwardsville, IL 62026-1800
Tel: (618)-650-2815, Fax: (618)-650-2555
Email: hzhou@siue.edu

Shaoqiang Chen, M.S.I.E.
Graduate Research Assistant
Center for Urban Transportation Research, University of South Florida
4202 E. Fowler Ave., Tampa, FL 33620
Tel: (813)-974-9795, Fax: (813)-974-5168

Peter Hsu, P.E.
District Safety Program Engineer
Florida Department of Transportation
11201 N McKinley Dr.
Tampa, Florida 33612
Tel: (813) 975-6251, Fax: (813) 975-6278
Email: ping.hsu@dot.state.fl.us

ABSTRACT

With the increase of number of overweight children, how to reduce obesity and improve their health condition has recently become a very important research area. Besides medication and diet therapy, one important treatment is to let children increase exercise through walking/biking from home to school. Currently, only a small portion of the students in the United States walk or bike to school, while most of them use family vehicles or school buses. This fact results from many potential factors.

In this paper, survey data of students' travel modes from both parents and students were collected at 18 schools (16 elementary and 2 middle schools) in Pinellas County, Florida. A new diagnosis approach was used to pin down the factors significantly affecting students' travel modes. The analysis is conducted in multiple perspectives, including (1) overview perspective which gives the general statistical information of each potential factor, (2) forward direction perspective that explores the cause-effect (how walking/biking rate changes as different factor's levels change), and (3) backward direction perspective that can be used to identify the similar properties of the student group with the same travel mode (walking/biking).

Further diagnosis at each individual school identified more factors that significantly affect the walking/biking rate. Generally, students living in different distance intervals are subject to different barriers, whereby security and safety is the primary factor of concern for short distance interval people, while distance is the primary factor of concern for those who live farther away from the school. The multi-perspectives diagnosis proved to be an effective method to mathematically search the necessary-sufficient condition for increasing students' walking/biking rate. Finally, a logistic regression model was developed to quantify the impacts of significant factors on walking/biking rate.

INTRODUCTION

Due to obesity and worsening health conditions of children, researchers put more and more efforts to develop efficient treatments in recent decades. Among different therapies, physical treatments play an important role in reducing obesity. That is to encourage children to do more exercise everyday, in which walking/biking to school is designed to as an equivalent part before and after school. However, only a very small portion of students choose to walk or bike to school. The Safe Routes to School (SRTS) program is thus developed, which originated from Denmark in 1976 and aims to encourage elementary and middle school students to walk or bike to school by providing safer and more comfortable routes to students.

In the United States, studies that explore the potential conditions on which students' travel behavior depends upon have been conducted before the SRTS program was implemented. Research in the literature has shown that students' travel behavior to school is a complicated socio-economic activity, which is affected by many potential factors such as household and the household location [1, 2]. Economic factors (e.g., travel cost, income, expense, etc.) and Demographic factors (such as gender and ethnicity) were demonstrated as important factors [2]. Travel time is also a significant factor affecting students' travel modes [2, 3]. Travel time is an indirect reflection of distance. As distance increases, more time is needed to walk/bike to school, and there is a greater concern with safety issues such as traffic safety and crime that are exposed on the way. The study has shown that distance, traffic, and crime are three key factors preventing students from walking/biking to school [4]. In the real world, there is often more than one single significant factor that influences students' travel mode [5]. Previous research concludes that under different conditions (locations, units, and time, etc.), there are different important factors that have corresponding impacts on students' travel modes, in particular, walking/biking. Therefore, an efficient approach is necessary to facilitate the efforts to identify the significant factors and quantify their impacts. In the literature, a statistical test such as chi-square test was employed to explore relationships between level of cycling and demographics, objective environmental factors, perceptions of the environment and attitudes [6]. A multivariate logistic model has been developed to quantify the relative safety of bicycle route based on bicycle crash data in the four years [8]. Moreover, a multinomial logit model [1] was fitted to estimate students' travel mode choice to school. Logistic regression method [7] has shown to be an effective method to quantify the factors' impacts. However, few statistical test methods were used in testing the relation between students' choice on walking/biking and potential influential factors. No modeling approach has been well developed exclusively for predicting the impacts on walking/biking rate, which is very important to the success of SRTS program.

In this paper, a new statistical diagnosis approach was applied to conduct a sequential search the necessary-sufficient significant factors in multiple perspectives. A binary logistic regression model was used to quantify the factors' impacts on walking/biking rate. The data was collected from a survey on student's walking/biking to school for 18 schools (16 elementary and 2 middle schools) in Pinellas County, Florida. The survey forms [9, 10] and online input tools designed by the National Center for Safe Routes to School (SRTS Clearinghouse) were used for both students and parents. A total of 644 classrooms were surveyed, with 347 tally sheets returned by teachers and a student participation rate of 53.9%. A total of 5,885 parent surveys were distributed, and 2,551 were returned, a response rate of 44%.

SURVEY DATA ANALYSIS FROM DIFFERENT PERSPECTIVES

To perform multiple perspectives analysis, questions in the survey were treated as impact factors. Different choices of each question were treated as different factor levels. For example, the student's grade is a factor, and the grades from K through 8^{th} grade are 9 different levels. Under this setting, data can be analyzed in three perspectives, namely, overview perspective, forward direction perspective, and backward direction perspective.

The overview perspective analyzes how different factor levels distribute. It gives a general picture about the basic descriptive statistics from the survey, such as the distribution of students' travel modes, grades, etc. An overall primary issue of concern can be obtained in this perspective, which will be used as a condition in forward perspective. The forward direction perspective is cause-effect studies under different condition settings, i.e., analysis of how the factor levels change influence the students' walking/biking rate. The backward direction perspective, in return, explores the similar properties of among those who already walk/bike to school. Mathematically, the forward direction perspective provides an opportunity to search the sufficient conditions for increasing walking/biking rate, while the backward direction perspective helps to figure out the necessary conditions. Figure 1 shows the flowchart of the multi-perspectives analysis approach.

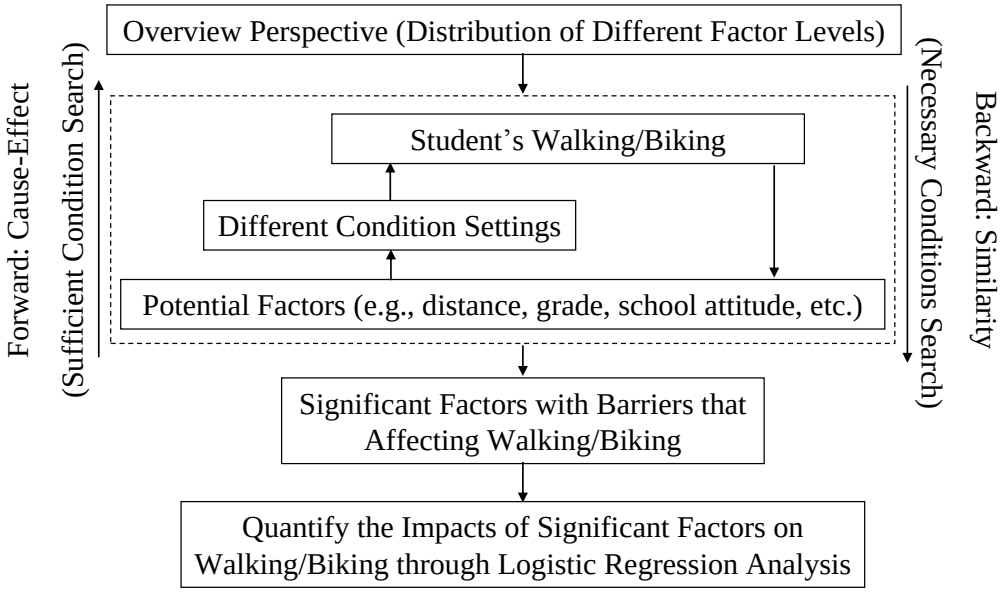
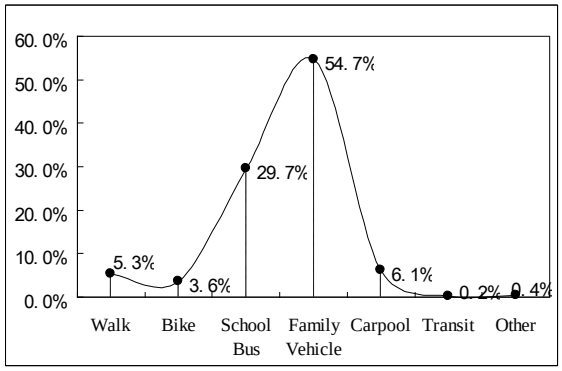


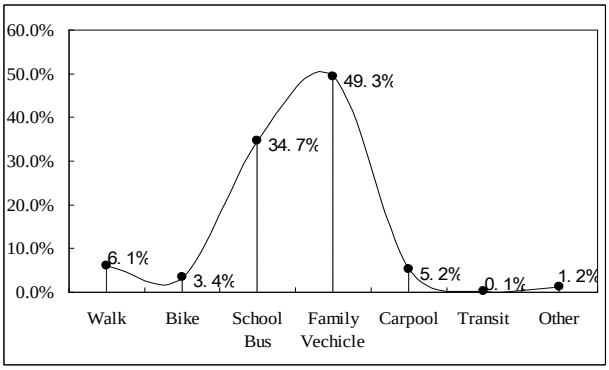
FIGURE 1 Flowchart of the Multi-Perspectives Analysis Approach

Descriptive Statistics of Survey Data from Different Perspectives

1) Overview perspective:

Figure 2 presents the distribution of travel modes from both parent and student surveys. It indicates that the answers from parents and their children are very consistent. Figure 3 shows the three day walking/biking rate from Tuesday to Thursday. There is very slightly difference between three different weekdays. The latest survey forms in reference [10] include three weekday survey for students in the classroom.





A. Distribution of Travel Modes (Parent) B. Distribution of Travel Modes (Student)

FIGURE 2 Distributions of Travel Modes

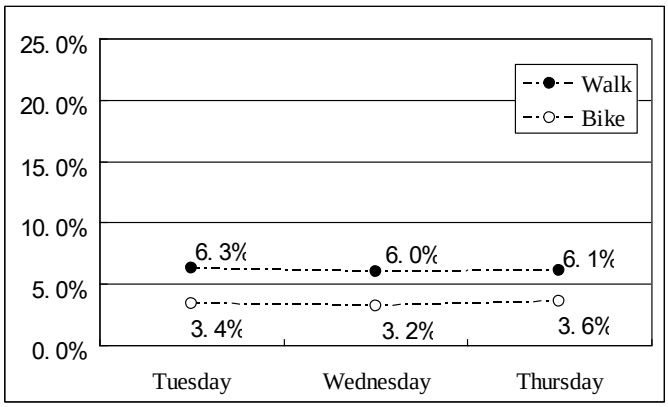


FIGURE 3 Distributions of Walking/Biking Rate among the Weekdays (Student Survey)

The basic descriptive statistics are summarized in Table 1. It is obvious that a considerable amount of parents' attitudes towards walking and biking are positive. In total, 32.6% of parents think that it is very fun and fun to walk/bike to school, 71.7% of parents think that it is very healthy and healthy to walk or bike to school. The percentage of students walking and biking to school is approximately 8.9%. The majority of the students choose school buses or family vehicles. The low walking/biking rate may attribute to distance, travel time (which is an indirect reflection of distance), school attitudes, and students' grade. Approximately 28.5% people live in the distance that is practical for walking or biking to school (less than 1 mile). The parent survey results showed that only a small potion of schools hold positive attitudes towards walking/biking. 58.0% parents will never allow children walking/biking alone to school. 75.5% of all surveyed students are elementary school students (K-5th grades). Figure 4 shows the ranks of issues affecting parents' decision toward students' walking/biking. The distance was ranked as No.1 issue. 67.7% parents selected it and 22% parents will change their minds if the distance also changes.

TABLE 1 Basic Descriptive Statistics (Percentage)

Distribution of Distance between Home and School					
< 1/4 mile	1/4 ~ 1/2 mile	1/2 ~ 1 mile	1 ~ 2 miles	> 2 miles	DK
9.4	7.2	11.9	17.7	46.9	4.6

Distribution of Normal Travel Time to School				
<5 min	5 ~ 10min	11 ~ 20 min	>20 min	DK
19.6	31.6	27.9	18.1	2.5

Distribution of Student's Grade Levels								
K	1	2	3	4	5	6	7	8
15.1	13.1	13.7	12.3	11.3	10.0	11.1	8.4	5.0

Distribution of Grade Levels That Students are Allowed to Walking/Biking Alone										
K	1	2	3	4	5	6	7	8	9plus	Never
0.2	0.5	1.2	4.0	5.3	6.4	10.6	3.2	6.3	0.7	58.0

Distribution of School Attitudes towards Walking/Biking				
Strongly Encourage	Encourage	Neutral	Discourage	Strongly Discourage
2.8	13.9	72.8	2.5	2.8

Distribution of Walking/Biking Enjoyment				
Very Fun	Fun	Neutral	Boring	Very Boring
10.1	22.5	48.1	4.1	4.1

Distribution of Walking/Biking Health				
Very Healthy	Healthy	Neutral	Unhealthy	Very Unhealthy
38.1	33.6	18.1	1.1	1.6

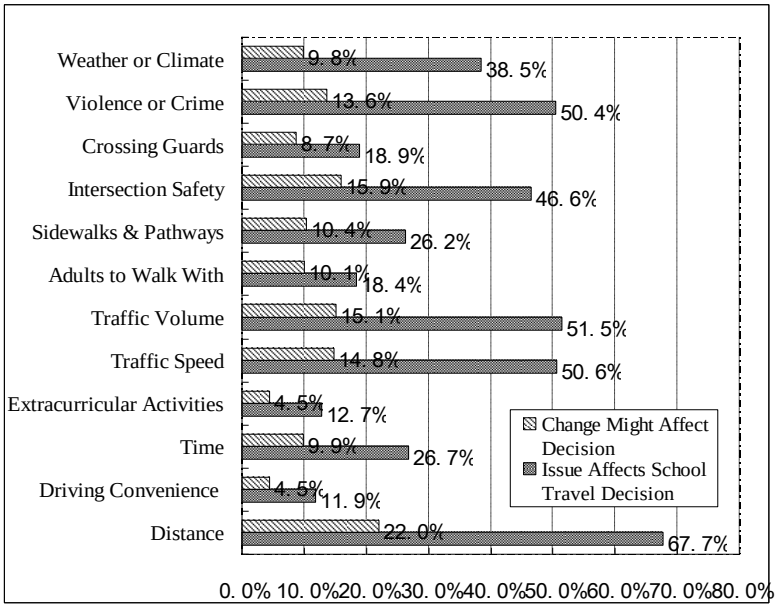


FIGURE 4 Ranks of the Issues affecting Parents Decision towards Children's Walking/Biking with Opportunities to Improve

Besides distance, travel modes choices are also affected by other barriers. Further descriptive statistical analysis was conducted for survey data on the students and parents (sample size = 728) who reported their home as located less than one mile from the school. As shown in Table 2, the percentage of walking/biking to school significantly increases by about 16%. The percentage of travel time less than 20 minutes also significantly increases by 18.5%. The more parents believed that their children's schools have encouraging attitudes toward walking/biking (up by 8.5%). And more parents believed that walking/biking is fun (up by 15%) and healthy (up by 11.7%). For a total of 728 families living at less than one mile to school, 25.8% children choose walking/biking. The non-positive attitudes from schools and parents are still considerable high. 72.4% of schools hold neutral and discouragement attitudes. 41.6% parents never allow their children to walk/bike alone to school). Figure 5 shows the ranks of issues affecting parents' decision on walking/biking. The main obstacle for walking/biking is violence or crime (about 50.4%).

TABLE 2 Basic Descriptive Statistics within 1 mile (Percentage)

Distribution of Travel Modes to School						
Waking	Biking	School Bus	Family Vehicle	Carpool	Transit	Other
16.2	9.6	4.9	60.7	7.6	0.1	0.8

Distribution of Normal Travel Time to School				
<5 min	5 ~ 10min	11 ~ 20 min	>20 min	DK
51.1	37.4	9.1	1.9	0.4

Distribution of Student's Grade Levels								
K	1	2	3	4	5	6	7	8
15.5	14.4	13.5	15.0	13.3	11.5	6.7	6.6	3.4

Distribution of Grade Levels That Students are Allowed to Walking/Biking Alone										
K	1	2	3	4	5	6	7	8	9plus	Never
0.1	1.1	2.9	9.5	9.5	12.2	14.4	2.5	6.0	0.1	41.6

Distribution of School Attitudes towards Walking/Biking				
Strongly Encourage	Encourage	Neutral	Discourage	Strongly Discourage
4.7	20.5	66.3	1.4	4.7

Distribution of Walking/Biking Enjoyment				
Very Fun	Fun	Neutral	Boring	Very Boring
17.0	31.2	39.6	3.4	1.9

Distribution of Walking/Biking Health				
Very Healthy	Healthy	Neutral	Unhealthy	Very Unhealthy
44.5	38.9	11.3	0.4	0.8

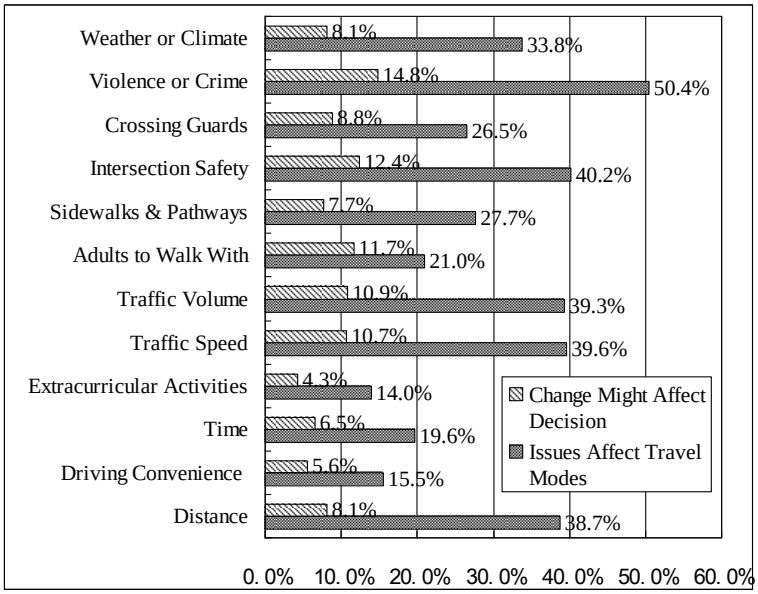


FIGURE 5 Ranks of the Issues affecting Parents Decision towards Children's Walking/Biking with Opportunities to Improve (within 1 mile)

Table 3 lists the ranking of the issues affecting parents' decision towards children's walking/biking to/from school at different intervals. It shows that for those living at less than 1 mile, traffic safety related issues (e.g., traffic speed, traffic volume, and intersection safety) closely follow behind the community safety issues. The traffic safety issues are not restricted in short distance intervals. They remain high rank beyond 1 mile areas. One other attractive phenomenon is that the community safety issues also occupy an important position ranking fourth as an issue of concern. This gives us a first impression about what are the most significant factors/issues affecting the students' walking/biking to school. Actually, the summary of comments from parent survey in the Appendix reflects that distance and safety (community and traffic safety) are the most important issues that affecting parents' decision on their children's walking/biking.

TABLE 3 Ranking of the Issues that Affected Parents Decision towards Children's Walking/Biking to/from School within Different Intervals

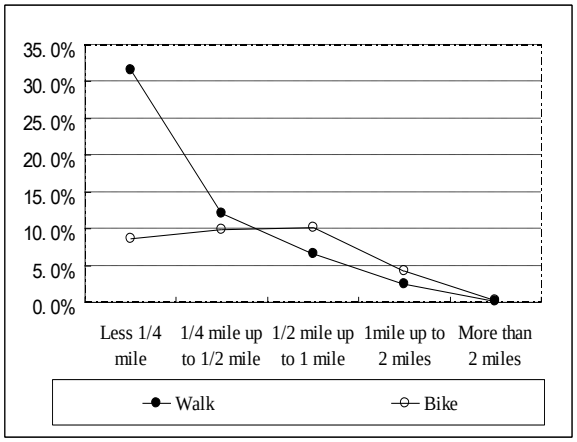
Int.(mile)	Dist.	Conv.	Time	Act	Speed	Vol	Adults	Sidew	Intersec	Guard	Crime	Weather
<0.25	2	12	10	11	5	3	9	7	6	8	**NO.1**	4
0.25~0.5	5	11	10	12	3	4	9	7	2	8	**NO.1**	6
0.5~1	5	11	10	12	2	3	9	7	4	8	**NO.1**	6
1~2	**NO.1**	11	8	12	3	2	9	7	5	10	4	6
>2	**NO.1**	12	7	11	3	2	9	8	5	10	4	6

Forward direction: cause-effect study of how walking/biking rate change by different factor levels:

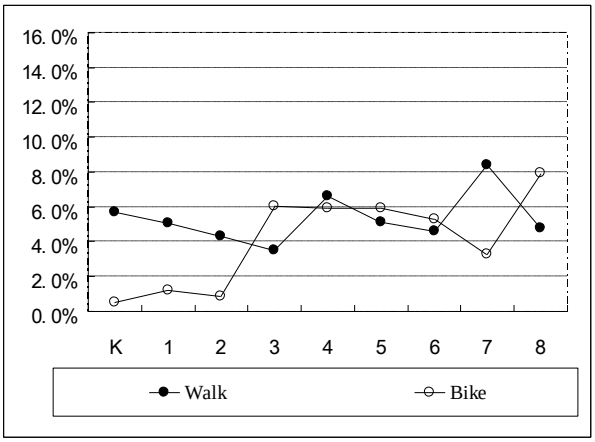
In the cause-effect study, a chi-square test and a cause-effect plot were used to search the significant factors. The chi-square test was used to assess whether paired observations on two variables/factors are independent. For instance, one variable is students' travel modes (value 1 for walking/biking, 0 otherwise),

other variables are demographics variables (e.g., grade, gender, and distance) and subjective variables (e.g., school attitudes towards walking/biking, enjoyment, and health). The cause-effect plot visualizes how the travel modes changes as values of other variables changes. In the plot, the vertical axis denotes the walking/biking rate, and the horizontal axis represents factor levels.

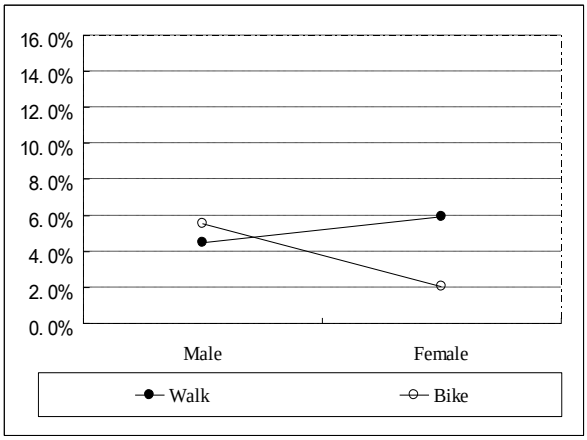
Figures 6 and 7 illustrate the cause-effect relation between walking/biking rate and demographics and subjective factors. The cause-effect plots reveal that the biking rate within 1 mile almost stays at a constant level (about 10%), while the walking rate drops significantly as distance increases from the 0.25 mile interval to the 0.5 mile interval. This matches a common sense that within very short distance region, students' are more likely to go to school on via walking as they don't need to go across too many intersections. As the distance increase, biking through blocks and intersections instead of walking are more convenient. Generally, the walking/biking rate decrease distance increases, which indicates a negative correlation.



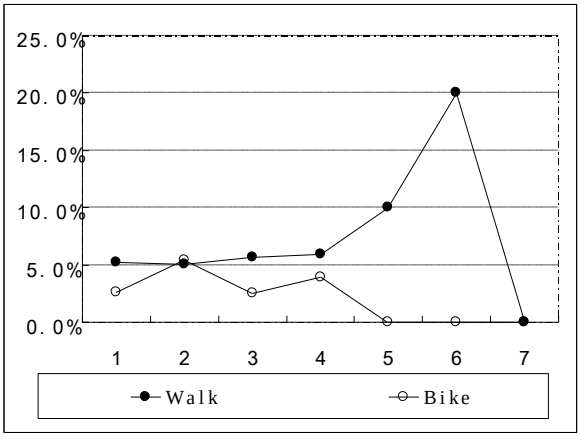
A. Walking/Biking Rate by Distance



B. Walking/Biking Rate by Grade Levels



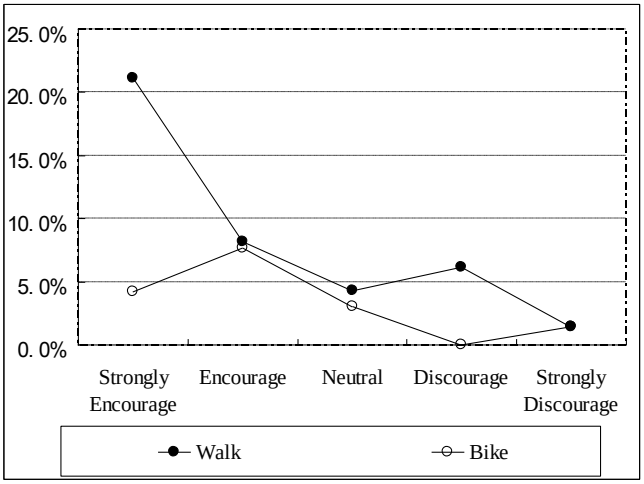
C. Walking/Biking Rate by Gender



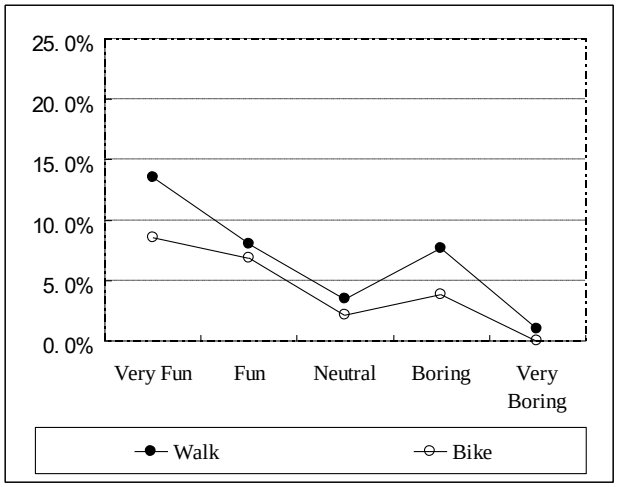
D. Walking/Biking Rate by Family size

FIGURE 6 Cause-Effect plot of Walking/Biking Rate by Demographics Factors

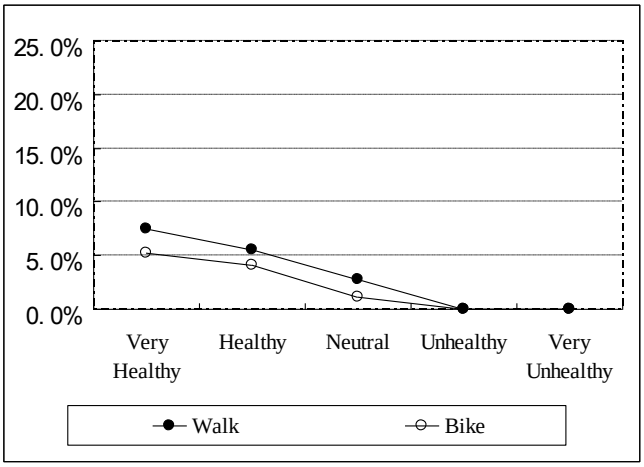
Averagely, large walking/biking rate is concentrated in middle level grades (3^{rd}-6^{th}). Low grade students (K - 2^{nd}) prefer walking to biking. After certain grade level (3^{rd}), the walking rate and biking rate are almost equal averagely. This reveals the fact that when children are too young they may not able to use a bike, while older children know how to bike. Other plots in Figures 5 and 6 can be interpreted in a similar way. In the cause-effect plot, some points behave in a unique way (e.g., point 6 and 7 of walking in Figure 6D), which makes it difficult to find the practical meaning. This is due to the small sample size for those points (t5 families have 6 children and 2 families have 7 children).



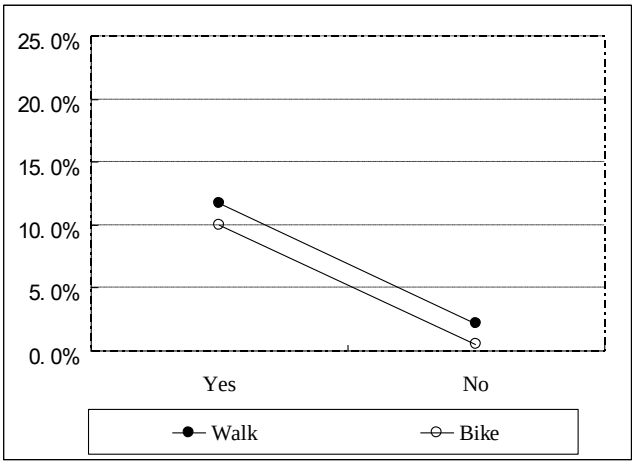
A. Walking/Biking Rate by School Attitudes



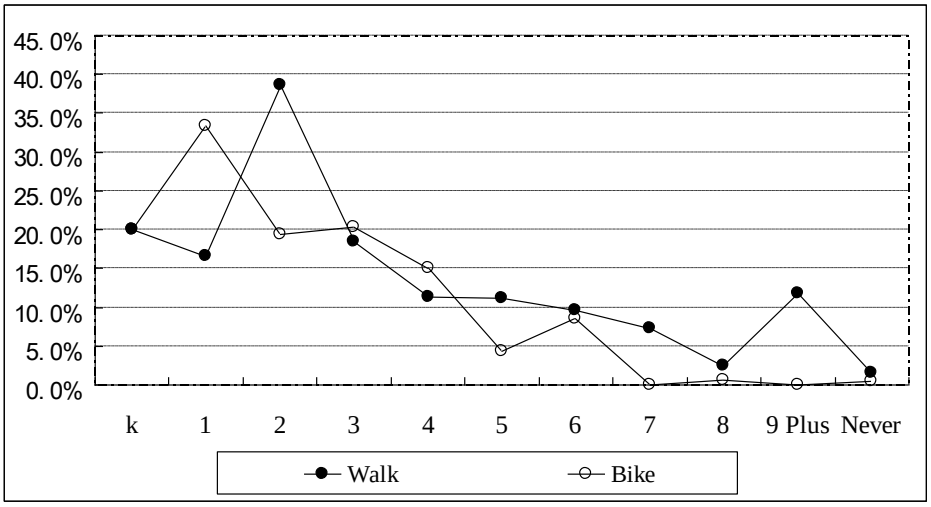
B. Walking/Biking Rate by Enjoyment



C. Walking/Biking Rate by Health



D. Walking/Biking Rate by Student Attitudes



E. Walking/Biking Rate by Allowable Grade Levels

FIGURE 7 Cause-Effect plot of Walking/Biking Rate by Subjective Factors

Tables 4 and 5 summarize the statistics in contingency tables of travel modes and other variables from the parent survey. Table 6 gives the chi-square test results for all the demographics and subjective factors. From the test results, most of demographics and subjective factors are statistically significant (α level = 0.05), except for gender and family size.

TABLE 4 Student Travel Modes and Demographics Variables

Demographics	Travel Mode							
	Walk	Bike	School Bus	Family Vehicle	Carpool	Transit	Other	Total
Grade								
Kindergarten	22(5.7%)	2(0.5%)	60(15.5%)	282(73.1%)	16(4.1%)	1(0.3%)	3(0.8%)	386
Grade 1	17(5.1%)	4(1.2%)	53(15.9%)	238(71.3%)	21(6.3%)	1(0.3%)	0	334
Grade 2	15(4.3%)	3(0.9%)	81(23.2%)	233(66.8%)	17(4.9%)	0	0	349
Grade 3	11(3.5%)	19(6.1%)	66(21.0%)	196(62.4%)	20(6.4%)	0	2(0.6%)	314
Grade 4	19(6.6%)	17(5.9%)	62(21.5%)	166(57.6%)	23(8.0%)	0	1(0.3%)	288
Grade 5	13(5.1%)	15(5.9%)	60(23.6%)	139(54.7%)	24(9.4%)	1(0.4%)	2(0.8%)	254
Grade 6	13(4.6%)	15(5.3%)	174(61.5%)	64(22.6%)	15(5.3%)	1(0.4%)	1(0.4%)	283
Grade 7	18(8.4%)	7(3.3%)	126(58.9%)	52(24.3%)	11(5.1%)	0	0	214
Grade 8	6(4.8%)	10(7.9%)	75(59.5%)	25(19.8%)	9(7.1%)	1(0.8%)	0	126
Gender								
Male	53(4.5%)	65(5.5%)	340(28.9%)	639(54.3%)	73(6.2%)	2(0.2%)	4(0.3%)	1,176
Female	81(5.9%)	28(2.0%)	417(30.4%)	756(55.1%)	83(6.0%)	3(0.2%)	5(0.4%)	1,373
Number of Children in the Family (Family Size)								
1	69(5.2%)	34(2.6%)	362(27.4%)	770(58.2%)	75(5.7%)	4(0.3%)	8(0.6%)	1,322
2	49(5.1%)	52(5.4%)	280(29.1%)	511(53.1%)	69(7.2%)	1(0.1%)	1(0.1%)	963
3	11(5.6%)	5(2.6%)	82(42.1%)	86(44.1%)	11(5.6%)	0	0	195
4	3(5.9%)	2(3.9%)	22(43.1%)	23(45.1%)	1(2.0%)	0	0	51
5	1(10.0%)	0	7(70.0%)	2(20.0%)	0	0	0	10
6	1(20.0%)	0	2(40.0%)	2(40.0%)	0	0	0	5
7	0	0	1(50.0%)	1(50.0%)	0	0	0	2
Distance								
Less than ¼ mile	76(31.5%)	21(8.7%)	7(2.9%)	119(49.4%)	13(5.4%)	1(0.4%)	4(1.7%)	241
¼ - ½ mile	22(12.0%)	18(9.8%)	13(7.1%)	118(64.5%)	11(6.0%)	0	1(0.5%)	183
½ - 1 mile	20(6.6%)	31(10.2%)	16(5.3%)	205(67.4%)	31(10.2%)	0	1(0.3%)	304
1 - 2 miles	11(2.4%)	19(4.2%)	76(16.8%)	311(68.8%)	33(7.3%)	0	2(0.4%)	452
More than 2 miles	1(0.1%)	3(0.3%)	569(47.7%)	554(46.4%)	62(5.2%)	4(0.3%)	1(0.1%)	1,194

TABLE 5 Student Travel Modes and Subjective Variables

Subjective Factors	Travel Mode							
	Walk	Bike	School Bus	Family Vehicle	Carpool	Transit	Other	Total
School Attitude								
Strongly Encourage	15(21.1%)	3(4.2%)	12(16.9%)	35(49.3%)	4(5.6%)	1(1.4%)	1(1.4%)	71(2.8%)
Encourage	29(8.2%)	27(7.6%)	76(21.5%)	197(55.6%)	22(6.2%)	0	3(0.8%)	354(13.9%)
Neither	80(4.3%)	56(3.0%)	567(30.6%)	1,028(55.4%)	116(6.3%)	4(6.3%)	4(0.2%)	1,855(72.7%)
Discourage	4(6.2%)	0	22(33.8%)	36(55.4%)	3(4.6%)	0	0	65(2.5%)
Strongly Discourage	1(1.4%)	1(1.4%)	30(42.3%)	35(49.3%)	4(5.6%)	0	0	71(2.8%)
Enjoyment								
Very Fun	35(13.5%)	22(8.5%)	33(12.8%)	143(55.4%)	19(7.4%)	3(1.2%)	3(1.2%)	258(10.1%)
Fun	46(8.0%)	39(6.8%)	133(23.3%)	317(55.4%)	34(5.9%)	0	3(0.5%)	572(22.4%)
Neutral	43(3.5%)	26(2.1%)	389(31.7%)	685(55.8%)	79(6.4%)	2(0.2%)	3(0.2%)	1,227(48.1%)
Boring	8(7.6%)	4(3.8%)	38(36.2%)	50(47.6%)	5(4.8%)	0	0	105(4.1%)
Very Boring	1(1.0%)	0	58(55.8%)	43(41.3%)	2(1.9%)	0	0	104(4.1%)
Health								
Very Healthy	73(7.5%)	51(5.2%)	250(25.7%)	522(53.7%)	69(7.1%)	3(0.3%)	4(0.4%)	972(38.1%)
Healthy	47(5.5%)	35(4.1%)	240(28.0%)	475(55.5%)	54(6.3%)	0	5(0.6%)	856(33.6%)
Neutral	13(2.8%)	5(1.1%)	160(34.6%)	264(57.1%)	19(4.1%)	1(0.2%)	0	462(18.1%)
Unhealthy	0	0	13(48.1%)	12(44.4%)	2(7.4%)	0	0	27(1.1%)
Very Unhealthy	0	0	16(38.1%)	22(52.4%)	3(7.1%)	1(2.4%)	0	42(1.6%)
Permitted to Walk or Bike Alone								
Kindergarten	1(20.0%)	1(20.0%)	0	1(20.0%)	1(20.0%)	1(20.0%)	0	5(0.2%)
Grade 1	2(16.7%)	4(33.3%)	1(8.3%)	4(33.3%)	1(8.3%)	0	0	12(0.5%)
Grade 2	12(38.7%)	6(19.4%)	4(12.9%)	8(25.8%)	1(3.2%)	0	0	31(1.2%)
Grade 3	19(18.4%)	21(20.4%)	17(16.5%)	39(37.9%)	6(5.8%)	0	1(1.0%)	103(4.0%)
Grade 4	15(11.3%)	20(15.0%)	24(18.0%)	65(48.9%)	8(6.0%)	0	1(0.8%)	133(5.2%)
Grade 5	18(11.1%)	7(4.3%)	27(16.7%)	96(59.3%)	14(8.6%)	0	0	162(6.4%)
Grade 6	26(9.6%)	23(8.5%)	63(23.2%)	136(50.2%)	18(6.6%)	0	5(1.8%)	271(10.6%)
Grade 7	6(7.3%)	0	32(39.0%)	40(48.8%)	4(4.9%)	0	0	82(3.2%)
Grade 8	4(2.5%)	1(0.6%)	63(39.4%)	85(53.1%)	4(2.5%)	2(1.3%)	1(0.6%)	160(6.3%)
Grade 9+	2(11.8%)	0	11(64.7%)	4(23.5%)	0	0	0	17(0.7%)
Never	22(1.5%)	6(0.4%)	484(32.7%)	869(58.8%)	94(6.4%)	2(0.1%)	1(0.1%)	1,478(57.9%)
Student Attitudes								
Yes	90(11.7%)	77(10.0%)	85(11.1%)	445(57.9%)	65(8.5%)	2(0.3%)	5(0.7%)	769(30.1%)
No	38(2.2%)	9(0.5%)	658(37.9%)	931(53.7%)	91(5.2%)	3(0.2%)	4(0.2%)	1,734(68.0%)

TABLE 6 Chi-Square Test for the Factors in the entire Parents' Survey

Factors	Significant Value
Distance	0.000
Grade Levels	0.002
Gender	0.064
Family Size	0.406
School Attitudes	0.000
Enjoyment	0.000
Health	0.000
Allowable Grade Levels	0.000
Student's Attitudes	0.000

Chi-Square tests were also conducted for the survey data at different distance intervals. The test results are summarized in Table 7.

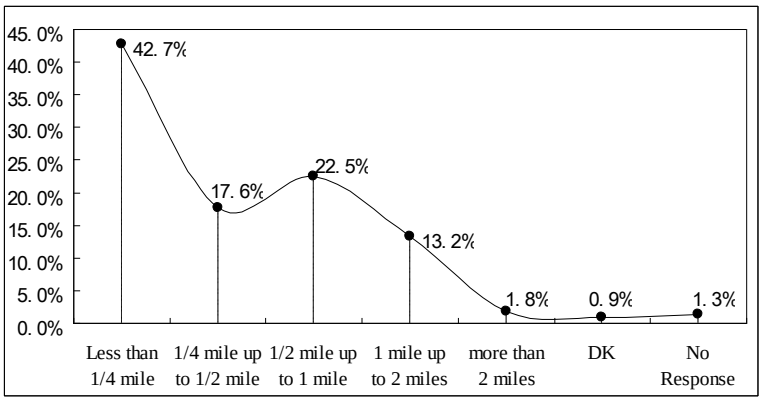
TABLE 7 Chi-Square Tests for the Factors in Different Distance Intervals

Dist Intervals (mile)	**Significant Values of Factors**								
	Dist	Grade	Gender	Family Size	School Attitudes	Enjoyment	Health	Allowable Grade	Student's Attitudes
<0.25		0.329	0.262	0.329	0.457	0.021	0.197	0.000	0.084
0.25~0.5		0.021	0.047	0.306	0.004	0.625	0.383	0.000	0.000
0.5~1		0.000	0.052	0.004	0.092	0.106	0.016	0.000	0.000
Over all <1	0.000*	0.000	0.030	0.284	0.001	0.000	0.001	0.000	0.000
1~2		0.041	0.405	0.525	0.104	0.001	0.760	0.000	0.000
>2		0.580	0.906	0.988	0.911	0.001	0.599	0.000	0.000
Over all >1	0.000	0.152	0.467	0.689	0.247	0.000	0.130	0.000	0.000

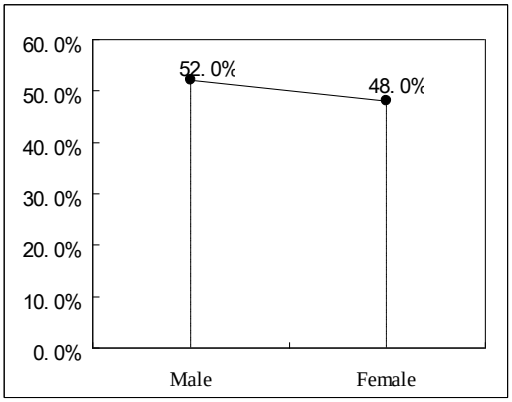
***** Within 1 mile, there are three distance intervals in all, of which the closest distance interval contains the largest amounts of students who walk or bike (97), compared with those of two other levels (51 and 40). It thus indicates that the distance and walking/biking rate are mutually independent of one another within 0.25 mile.

Backward direction: similarity study of what is in common within the walking/biking group:

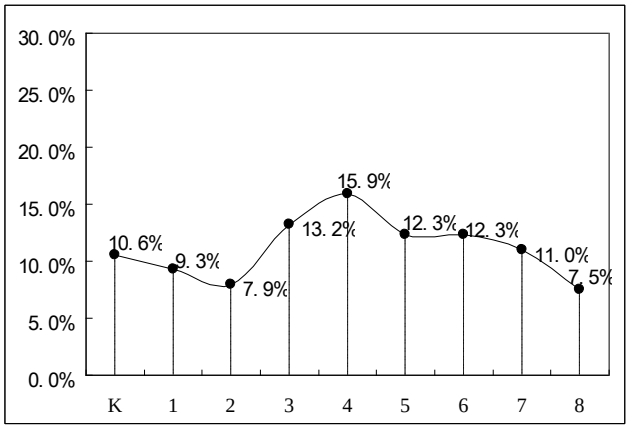
The potential factors to be studied here are all the factors included in overview perspective section and forward direction perspective section. The sample size of this group is 227. Figures 8 and 9 summarize the demographic as well as subjective similarities within this group.



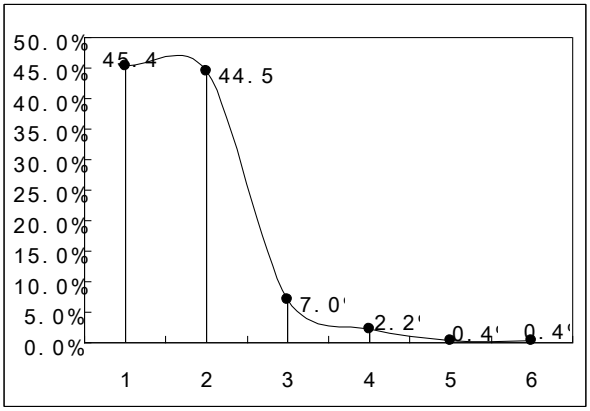
A. Distance Similarities



B. Gender Similarities



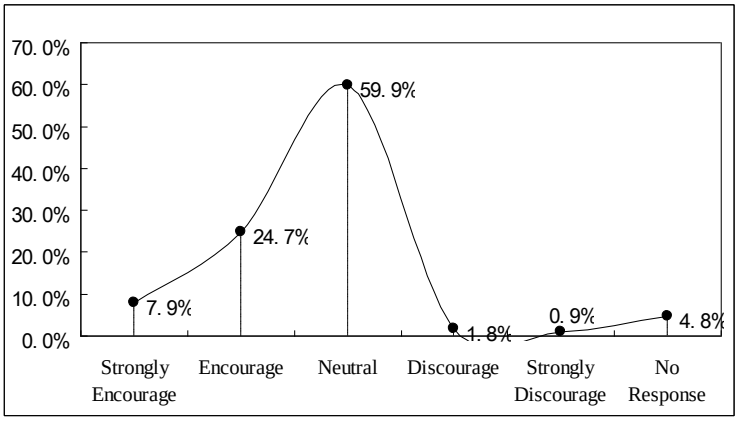
C. Grade Levels Similarities



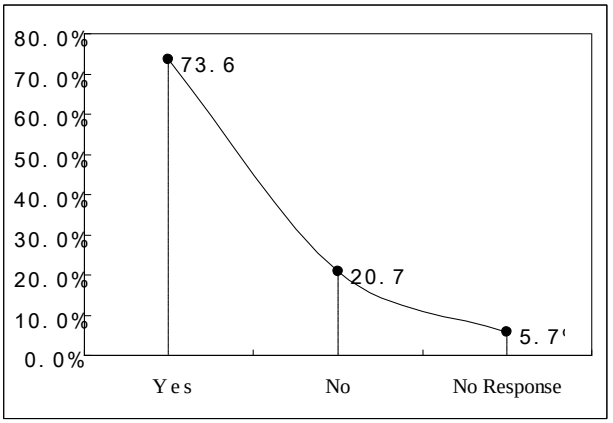
D. Family Size Similarities

FIGURE 8 Demographic Similarities within Walking/Biking Group

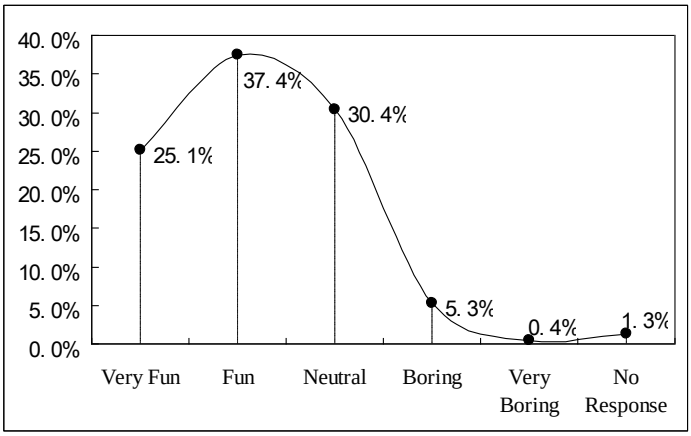
Within this group, we can easily tell that people tend to live in close proximity to the school (within 1 mile). In addition, except for those who did not respond, all other people hold non-negative views on health factors; and almost all of them hold non-negative attitudes on enjoyment factors. More parents are willing to allow their children to walk/bike alone to school at certain grade levels. Moreover, children prefer to ask for parents' permission for walking/biking. For school attitudes, however, the non-positive attitudes are still counted the majority of the time. Most of the families have one or two children. Actually, the sample size of the families with more than three children is very small even among all the survey data. This explains the large percentage difference between small size families and large size families, which is similar to the case of Figure 6D. The plot also shows that students of middle level grades (3^{rd}- 6^{th}) are the majority of who walk or bike to school. There is no significant difference between males and females.



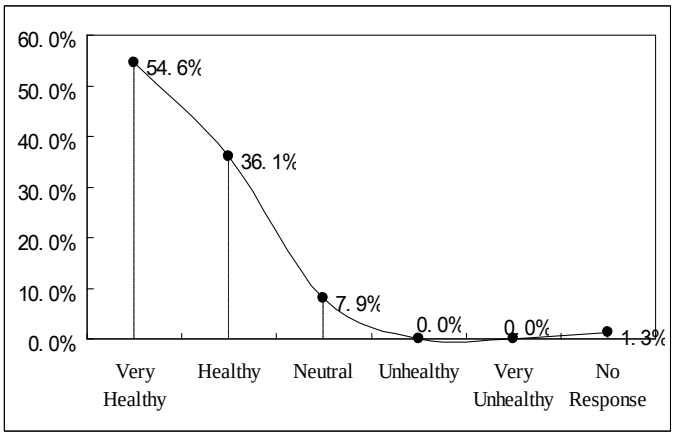
A. School Attitudes Similarities



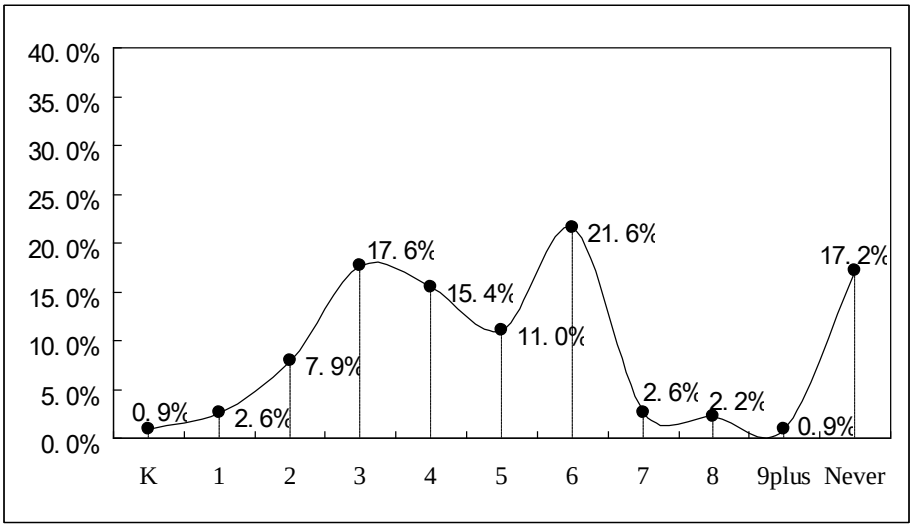
B. Student's Attitudes Similarities



C. Enjoyment Similarities



D. Health Similarities



E. Allowable Grade Levels Similarities

FIGURE 9 Subjective Similarities within Walking/Biking Group

As for the barriers in parents' minds, Figure 10 tells us that distance is still the primary concern among parents within this group, followed closely by crossing guards and sidewalks (safety related issues). This indicates that the current SRTS engineering program (installing more crossing guards, building more sidewalks, and reducing traffic speed) will have a great effect on increasing the number of students who walk or bike to school.

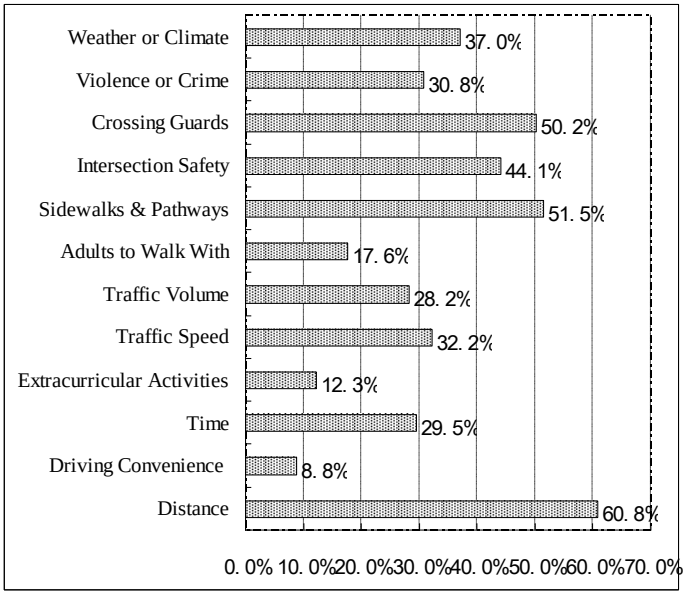


FIGURE 9 Ranks of the Issues Affecting Parents Decision towards Children's Walking/Biking (within the Walking/Biking Group)

Quantify the Impact of Significant Factors on Students' Walking/Biking Rate

From the multiple perspectives analysis, we can see that under different conditions (e.g., different distance setting), the significant factors are different. Generally, within 0.25 mile, the most important factors are enjoyment and allowable grade, with crime as the primary obstacle for walking/biking. Within 1 mile, expect family size, all other factors are significant and crime is the major concern; beyond 1 mile, however, only distance, enjoyment, allowable grade and student attitudes are significant factors, with distance as the primary barrier. Generally, the results tell us that the largest barriers of walking/biking are categorized into two types: distance and safety (community and traffic safety) issues. Safety issues however, were not designed as multi-levels factors in the survey.

Binary logistic regression model is chosen to quantify the impacts of significant factors. Unlike regular linear regression, in which the response is continuous dependent variables, the logistic regression studies the relation between discrete binary or dichotomous variables (dependent variables, e.g., for the problem at hand, we can denote walk/bike = 1, otherwise = 0) and the factors (independent variables). The binary logistic regression model is formulated as follows:

$$p(Y=1\,|\,\mathbf{x}) = \pi(\mathbf{x}) = \frac{e^{g(\mathbf{x})}}{1+e^{g(\mathbf{x})}}, \qquad p(Y=0\,|\,\mathbf{x}) = 1-\pi(\mathbf{x}) \tag{1}$$

where $g(\mathbf{x}) = \beta_0+\boldsymbol{\beta}_1\mathbf{x}_1+\boldsymbol{\beta}_2\mathbf{x}_2+\ldots+\boldsymbol{\beta}_p\mathbf{x}_p$, and the $\mathbf{x}_i$'s denote the independent variables. In our case, $\mathbf{x}$ represents all the significant factors affecting walking/biking rate. For the variables including k categorical levels, k-1 "design variables" (dummy variables) are generated to indicate each level. For example, if $\mathbf{x}_i$ denotes enjoyment with five levels (very fun, fun, neutral, boring, very boring), four design variables $x_{i1} \sim x_{i4}$ are generated. The variable can be coded as shown in Table 8. The conditional mean of Y given $\mathbf{x}$ is thereby equal to the quantity of $\pi(\mathbf{x})$. We can see that the response of binary logistic model becomes a probability of certain outcome, i.e., in our case, probability of 1 (walk) or 0 (bike). Maximum likelihood estimation (MLE) is the method used in fitting the model. For details of model fitting and MLE, refer to [7] and the references therein.

It should be note that one may choose other regression analysis (e.g., linear regression) to construct a

unit-wise model. In particular, the dependent variables becomes walk/biking rate of certain unit (e.g., a school); meanwhile, independent variables changes to be unit-wise accordingly, such as percentage of grade levels in each school, percentage of different distance levels in each school, etc. In this case, each individual school's data results in one point. This implies that we have to collect survey data from enough number of schools, not just from single school to fit the model. It thus lacks efficiency compared with binary logistic regression model. Due to that along with the multi-perspectives analysis, survey data from any single school is enough to fit a model (every parent survey is one data point).

TABLE 8 An Example of Coding Multi-Levels Categorical Factors into Design Variables

	x_{i1}	x_{i2}	x_{i3}	x_{i4}
Very Boring*	0	0	0	0
Boring	1	0	0	0
Neutral	0	1	0	0
Fun	0	0	1	0
Very Fun	0	0	0	1

*****First level is used as reference level

As an example to express the idea for quantifying the impacts of significant factors, wet illustrated the model fitting for < 0.25 mile case (241 data points in total). Although crime was not well designed as a multi-levels factor in the survey, we still add it in the model because of its significant importance. The variables are defined as:

- Y: Travel Modes, with Walk/Bike =1, Otherwise = 0.
- $\mathbf{X}_1$: Enjoyment, five levels, i.e., very fun, fun, neutral, boring and very boring. Four design variables are generated $\mathbf{X}_1 = (x_{11}\ x_{12}\ x_{13}\ x_{14})^T$. The following variables are defined similarly.
- $\mathbf{X}_2$: Allowable Grade, nine levels, i.e., 1^{st} -8^{th} and never, with eight design variables generated.
- $\mathbf{X}_3$: Crime, regarded to have two levels, i.e., yes and no, with 1 design variables generated.

The model fitting results are given by Table 9. In the table, "coefficients in the logit" denote those $\boldsymbol{\beta}i$'s, which are the quantified impacts of the significant factors. The constant is the intersection of the model. As an interpretation, take crime for example, setting other factors aside; if crime is not a barrier, the probability of walking/biking rate will be $e^{1.129}/(1+ e^{1.129}) - e^{0}/(1+ e^{0}) = 0.3$ higher than that of the situation with crime as a significant obstacle. Other numerical results can be interpreted similarly.

TABLE 9 Results of Quantifying the Impacts of Significant Factors (<0.25 mile)

Variables	Coefficients in the Logit
Constant (β_0)	-23.840
$\mathbf{X}_1$ (Enjoyment)	
x_{11}	22.468
x_{12}	21.923
x_{13}	21.872
x_{14}	22.935
$\mathbf{X}_2$ (Allowable Grade)	
x_{21}	1.002
x_{22}	3.360
x_{23}	1.476
x_{24}	1.050
x_{25}	0.353
x_{26}	1.230
x_{27}	23.120
x_{28}	-0.451
$\mathbf{X}_3$ (Crime)	
x_{31}	1.129

DISCUSSION AND FURTHER DIAGNOSIS AMONG INDIVIDUAL SCHOOLS

The analysis in the aforementioned section is based on data from all the combined schools. However, different schools are subject to unique situations. In fact, the multi-perspectives approach can be applied to an individual school. We thus conduct the research for individual school in this section, particularly, those schools with highest and lowest walking/biking rate. Table 10 summarized the important statistics of each school.

For each school, we collected two more data factors, i.e., road conditions (with residential density) and sidewalk number around the school. These factors were not designed in the survey. However, after exploring through the multi-perspectives analysis, we realized that they are also of vital importance to the walking/biking rate. Among the schools with highest walking/biking rate (the first three schools), a relatively large portion of students live within 1 mile distance region in average. However, the schools with lower walking/biking rate are likely too far away from the children's families (much less within 1 mile percentage). With regard to car transportation middle school is a representative case in terms of distance, which is highlighted. Azelea Elementary is an exceptional case. Because that traffic safety and residential density overtake distance issue for this school. Generally, more accessible roads make students easier to walk and bike, and areas with denser residence give students a safer feeling. Sidewalk conditions are another important issue. A road without a sidewalk is usually unsafe to walk and bike on. For each school area, however, parents take different priorities on the important factors. For instance, Starkey has a higher walking/biking rate than Lealman Avenue. However, the within 1 mile percentage of Starkey is smaller than that of Lealman Avenue. In this case, we can see that it may be the community safety issues (e.g., crime) that lower the walking/biking rate in Lealman Avenue. With the analysis among schools, we realize two points. First, every school should be treated differently due to its own unique situation using the multi-perspective approach. The same significant factors may even have different impacts for different schools, which results in different $\boldsymbol{\beta}_i$ in Eqn. (1). For another, there is still room to

improve the survey in that some significant factors (e.g., road conditions, sidewalk number, speed limit, etc.) that has not been well designed in the survey. These factors, in parents' minds may even more important than those factors such as gender, grade levels, health and enjoyment, etc. In fact, some subjective factors are the derivation of the factors that have not been well designed in the survey. For example, within short distance intervals, attitudes of parents and/or schools on walking/biking may be subject to the community and traffic safety issues. If issues such as crime are designed to be a multi-level factor, we can analyze the cause-effect as well as similarities between the crime rate level and parents' attitude level, which is also connected with walking/biking rate.

TABLE 10 Statistics of Each School (Rank by Walking/Biking Rate to School)

School Name (with Number of Surveys Returned)	Road Conditions* Around School	< 1 mile	NO.1s and NO.2s Barriers Concerned	Sidewalk Number* Around School	Walk/Bike Rate (in Decreasing Order)
Clearview Avenue Elementary (12)	Access[4]	50%	Dist, Speed, Crime, Weather	1~2	33.3%
Seminole Middle (248)	Access[4]	35.5%	Distance, Crime	1	19.8%
Bardmoor Elementary (84)	Access[4]	34.5%	Distance, Traffic Speed	0~1	13.1%
Starkey Elementary (126)	Access[5]	32.54%	Distance, Traffic Volume	2	12.7%
Lealman Avenue Elementary (127)	Access[5]	43.3%	Distance, Crime	2	11.8%
Lake St. George Elementary (122)	Access-Mobility[2]	45.9%	Distance, Traffic Volume	1	11.5%
Bauder Elementary (194)	Access[3]	34.5%	Distance, Traffic Speed	1~2	11.3%
Highland Lakes Elementary (115)	Access[5]	27.83%	Distance, Crime	2	11.3%
Oakhurst Elementary (265)	Access[5]	38.5%	Distance, Traffic Volume	2	11.3%
Blanton Elementary (121)	Access**[4]	28.9%	Distance, Crime	2	9.9%
Seventy Fourth Street Elementary (51)	Access**[4]	25.5%	Distance, Traffic Speed	1~2	7.8%
Lakewood Elementary (39)	Access-Mobility**[4]	35.9%	Crime, Traffic Speed	2	7.7%
Carwise Middle (378)	Access[5]	9.0%	Distance (82.3%), Traffic Volume	2	5.6%
Tyrone Elementary (65)	Access-Mobility**[5]	26.2%	Distance, Traffic Speed	2	4.6%
Sawgrass Lake Elementary (159)	Access-Mobility[5]	23.3%	Distance, Crime	0~1	2.5%
Melrose Elementary (47)	Access[4]	17.0%	Distance, Crime	1	2.1%
Pasadena Fundamental Elementary (329)	Access[5]	11.2%	Distance, Traffic Volume	2	1.5%
Azelea Elementary (69)	Access-Mobility[2]	36.2%	Traffic Volume, Distance	2	0.0%***

***** Information obtained from Google Maps
****** 2-3 lanes in each direction on the road
******* Only 2 walking/biking in total, the percentage ≈ 0.0%
Residential density: 1-low, 2-median low, 3-median, 4-median high, 5-high

CONCLUSIONS AND FUTURE WORK

Conclusion

This paper develops a novel diagnosis approach for efficiently identifying the significant factors that affect students' walking/biking rate. Multiple perspectives analysis is the key for this approach, which drives us to mathematically search the necessary and sufficient significant factors whose impacts on walking/biking rate are quantified by the logistic regression model. In application, different condition settings lead to different results. Specifically, distance is the most significant factor and largest barrier for the long distance interval group. For

short distance interval, safety issues such as crime prevent children from walking/biking to school. Subjective factors (school attitudes, allowable grade, and student's attitudes in particular), are also significant factors in general. For different individual schools, however, the significant factors variates were due to unique situations around each school. Besides distance, we discovered that walking/biking rate increases as residential density around the school increase. Improvement of sidewalk conditions and an increase of the accessibility of the road also results in increasing the walking/biking rate in general. The results give us guidelines on the direction of how to improve walking/biking rate. For those unsafe areas, improvement could be made by strengthening the law. For the areas with fewer sidewalks, more sidewalks could be constructed along roads. For subjective factors such as school attitudes, education could be made within each school to encourage students to walk/bike to school.

Future Work

The results from this study show that there is still room for the SRTS survey to be improved. Community and traffic safety issues are crucial to the walking/biking rate. However they were not designed as multi-levels factors. In this regard, one can do some extra investigation for each parent in the future work, e.g., collect the crime rate levels (low, median, high) around each family. Furthermore, based on the multi-perspective approach, one can study interaction effects of multiple factors. The reason lies in that there may be correlation among some factors. For example, suppose that there are only two factors, distance and the number of sidewalks, in which, children may walk/bike to school unless the distance is too long and there are no sidewalks on their route. In this case, neither long distance nor the number of sidewalks results in children choosing other travel modes. Hence, distance and sidewalk number have negative correlation. The interaction effect study thus may uncover more interesting and valuable results.

ACKNOWLEDGEMENT

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APPENDIX: SUMMARY OF COMMENTS FROM PARENTS SURVEY

1. Distance and traffic safety concerned comments.
2. Crime and safety concerned comments (sex predator, children abductor, etc.).
3. Adults to walk with/enough amount of students walk together concerned comments.
4. Student' age concerned comments.
5. Availability of sidewalk (and crossing guard) concerned comments.
6. Start time of school concerned comments (such as too early, and dark in the morning).
7. Weight of backpack concerned comments (to heavy).
8. Comments with regarding to the last question (such as not relevant to the survey, offensive).