Flow Characteristics on Shared Hiking/Biking/Jogging Trails

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Flow Characteristics on Shared Hiking/Biking/Jogging Trails

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Trails shared by hikers, bicyclists, and joggers present the unusual traffic flow situation of a facility serving three classes of users with distinctly different flow characteristics. Data on typical trail volumes are summarized. A procedure developed by Botma to describe quality of flow on shared pedestrian/bicycle paths is then discussed. Data from two sites, the MKT Trail in Columbia, Missouri, and a riverside trail in Brisbane, Australia, were collected to describe speed and passing time characteristics on shared trails. The frequency of desired overtakings (passes) and potential conflicts on trails are estimated based on measured speeds and passing times using basic relationships of traffic flow theory. These estimates are then compared with measured values of overtaking frequency and delayed overtakings. The estimates for passing demand and potential conflicts were higher than the measured values for hikers passing hikers and joggers passing hikers. However, estimates for bike passing bike, bike passing jogger, bike passing hiker, and jogger passing jogger were found to be similar to the measured values. The results support the Botma framework for describing quality of flow on shared pedestrian/bicycle paths.

Many localities have provided trails shared by hikers, bicyclists, and joggers. Some of these trails serve significant transportation purposes, whereas others are overwhelmingly devoted to recreational use. In either case, these facilities present the unusual traffic flow situation of a facility serving three classes of users with distinctly different flow characteristics. The interactions between these three user groups are addressed here.

Information on shared trail volumes is given in the next section, followed by a brief review of quality of flow descriptions for facilities serving the bicycle mode. A procedure developed by Botma (*1*) to describe quality of flow on shared pedestrian/bicycle paths is then presented.

Data from two trails, one in Missouri and another in Australia, were collected to provide some understanding of the three types of users and interactions between the three groups. The data are used to

- Describe the flow characteristics on these shared hiking/bicycling (biking)/jogging trails;
- Describe the frequency of desired overtakings (passes) and potential conflicts on trails used by hikers, bicyclists, and joggers; and
- Compare estimates of desired overtakings and potential conflicts to measured values of overtaking frequency and delayed overtakings.

The results are used to indicate the potential accuracy of the Botma level of service measures for these types of facilities.

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BACKGROUND

Volumes on Shared Trails

Data on traffic volumes for multiple-use trails are scarce. Hunter and Huang (*2*), as part of the National Walking and Bicycling Study, described usage of both exclusive bicycle facilities and multiple-use paths (e.g., hikers, bicyclists, and joggers) in the United States. In a summary table for multiple-use paths, 13 sites in seven states were described. On bridges, volumes ranged from a low of 400/day (with 78 percent bicyclists and 22 percent walkers or joggers) on the 14th Street Bridge in Washington, D.C., to a high of 2,871 (41 percent bicyclists) over 12 hours on the Brooklyn Bridge. On trails, annual volumes ranged from 135,000 (65 percent bicyclists) to 400,000 (20 percent bicyclists).

The same study described hourly usage over 12 hours from one site in Raleigh, North Carolina. Hourly volumes ranged from approximately 0 to 14 for joggers, 18 to 60 for bicyclists, and 38 to 100 for pedestrians.

A study of a pedestrian/bicycle path in Brisbane, Australia, reported a 15-hour count near the central business district (CBD). The 15-hour total was 1,919, including 848 pedestrians and 1,071 bicyclists. The morning peak hour had 162 bikes and 72 pedestrians with a 74/26 directional split. The evening peak hour included 152 bikes and 135 pedestrians with a 62/38 directional split (Brisbane City Council Department of Development and Planning, unpublished data).

Describing Quality of Flow

Bicycle Facilities

Botma (*1*) described the Dutch guideline (*3*) for the required width of a separate bicycle path and determination of level of service (LOS) for bicycle facilities. Hindrance, which relates to the frequency of overtaking and meeting maneuvers, determines LOS.

Hindrance is described as the percentage of bicyclists that are hindered over a 1-km travel distance. The amount of hindrance depends on the type of maneuver (e.g., meeting or overtaking) and the space available for the maneuver (i.e., the path width). Hindrance scoring was based on perceived hindrance derived from user surveys. An overtaking counts as one hindrance, and a meeting of a traveler in the opposite direction counts as one-half of a hindrance. The number of meetings is determined by fundamental flow parameters (*4*).

When speed is normally distributed, desired overtaking frequency can be found from Wardrop's formulation (*4*):

$$F = Q^2\sigma \big/ \left[U\sqrt{\pi}\right] \tag{1}$$

where

F = frequency of desired overtakings,
Q = one-way flow rate,
σ = standard deviation of speed (0.83 m/sec in the Dutch manual), and
U = space mean speed (5.0 m/sec in the Dutch manual).

The result is referred to as *desired* overtakings because the effect of oncoming traffic, which could delay passes, is not considered. When oncoming traffic is light, one might expect most desired overtakings to be completed. When oncoming traffic is heavy, few desired overtakings would be completed.

Botma also described quality of flow with respect to mean time between events (MTBE). Events are maneuvers (passings or meetings). MTBE is the reciprocal of the frequency of events.

Shared Pedestrian/Bicycle Facilities

Botma (*1*) extended the concept of MTBE on bicycle facilities by adding in the effect of pedestrians within the traffic stream. This first led to a recommendation for LOS criteria for one-way pedestrian-bicycle paths.

One-Way Paths Pedestrians are assumed to seldom overtake other pedestrians. Therefore pedestrian LOS is determined by the frequency with which an average pedestrian would be overtaken by bicyclists. The total number of overtakings of the slower pedestrians by faster bicyclists can be determined by (*4*)

$$N_{f/s} = XTQ_f Q_s \left(1/U_s - 1/U_f\right) \quad (2)$$

where

$N_{f/s}$ = total number of overtaking of slower units by faster units (e.g., overtakings per km/h),
X = length of site,
T = time period considered,
Q_f = flow of faster group in subject direction,
Q_s = flow of slower group in subject direction,
U_f = mean speed of faster group, and
U_s = mean speed of slower group.

The frequency with which an average pedestrian will be overtaken by bicyclists can be derived from Equation 3.

Ignoring bicycles passing bicycles, bicycle LOS was taken to depend on the frequency with which an average bicyclist would overtake pedestrians (which can also be derived from Equation 3). Botma then used an average pedestrian speed of 1.25 m/sec and average bicycle speed of 5 m/sec to develop tables of service flow rates for both pedestrians and bicyclists.

Two-Way Paths For two-way shared paths, Botma assumed that both overtakings and meetings would affect LOS (with an overtaking, again, equal to one event and a meeting equal to one-half of an event). For pedestrians, LOS was based on meetings and overtakings by bicycles (and not other pedestrians). For bicyclists, LOS was based on meetings and overtakings involving both pedestrians and bicycles.

The results presented by Botma relied on the assumed speeds for bicycles and pedestrians above and an assumed standard deviation of speed (0.83 m/sec) for bicyclists. In discussing the results, Botma emphasized the importance of

- Collecting additional field data to better understand the distributions of speeds within the user groups,
- Determining the time required to complete overtaking maneuvers, and
- Understanding second-order interactions (e.g., when a meeting would occur during an overtaking maneuver).

The field study results described below address these three concerns.

FIELD STUDY

The study site in Missouri was the MKT Trail, a former railroad spur, now a recreational hiking/biking trail in Columbia, Missouri. The trail is level and straight and has a crushed rock surface with an average width of about 3 m. The surface wearing pattern indicates that users generally treat the trail as having one lane for each direction. This pattern of usage was confirmed by observation. The center of each “lane” has a firm surface for bicycle tires. The middle of the trail and the outside edges have significant amounts of loose gravel that bicyclists usually avoid. When bicyclists or joggers pass other users, they generally leave their own lane and complete the pass by traveling in the opposing lane. Individual walkers and joggers generally remain in the middle of each lane but will share the lane when traveling in pairs, resulting in each person encountering a somewhat rougher surface. The portion of the trail studied is close to the most popular access point near Stadium Boulevard.

The Australian site in Brisbane parallels the Brisbane River. The portion of the trail studied is straight and level with a smooth asphalt surface. A painted centerline divides the 2.9-m-wide path. Like the Columbia trail, the Brisbane trail generally operates as two one-way lanes. The portion of the trail studied is close to the Queensland University of Technology, the city’s CBD, and the city’s botanical gardens.

Data Collection

An observer with a stopwatch collected data to describe the following traffic flow characteristics.

- Average speed and speed distributions for each mode along a short (8-m to 16-m) section,
- Time required to pass other users,
- Passing maneuvers over a significant length (275 m) during 15-minute increments (in Brisbane), and
- Delayed passes over the same extended length during 15-minute increments (in Brisbane).

In Columbia, the data were collected on pleasant autumn weekend days when recreational usage was expected to be high. In Brisbane, the data were collected on pleasant Tuesdays between noon and 2:00 p.m., when users appeared to be primarily university student bicycle commuters and lunch-hour exercisers who were jogging or walking.

Speed and Overtaking Time

The flow characteristics of the two sites are summarized in Tables 1 and 2. Table 1 shows the characteristics of the speed distributions

TABLE 1 Speed Distributions of Each Group (m/s)

Speed Statistics	Hikers	Joggers	Bikers	All
Columbia				
Mean	1.59	2.87	5.95	3.39
Median	1.63	3.05	6.00	2.80
Standard Deviation	0.28	0.79	2.10	2.25
Coeff. of Variation	0.18	0.27	0.35	0.66
Minimum	0.92	1.08	1.23	0.92
Maximum	2.09	4.24	10.21	10.21
Count	40	33	35	108
Brisbane				
Mean	1.56	3.34	5.76	3.16
Median	1.60	3.32	5.80	3.01
Standard Deviation	0.24	0.44	1.33	1.79
Coeff. of Variation	0.15	0.13	0.23	0.57
Minimum	0.82	2.19	2.03	0.82
Maximum	2.17	4.79	9.88	9.88
Count	187	151	105	443

Coeff. = coefficient in Tables 1 and 2.

for the three user groups. The Columbia speeds were measured over 9 m and the Brisbane data over 8 m. For both sites, the mean jogger speed was almost twice the mean hiker speed, and the mean bicyclist (biker) speed was nearly twice the mean jogger speed. Among the three groups, the coefficient of variation (standard deviation divided by mean) was highest for bikers at both sites. The most striking difference between the two sites was in jogging speed. Compared with Columbia, the Brisbane joggers had higher mean speeds but a much lower standard deviation of speed. Each of the individual speed distributions appeared to be close to bell-shaped.

The time required for one individual to pass another is shown in Table 2. The time to pass was measured by an observer with a stopwatch. The pass began when the passer left the right side lane (left side in Brisbane) and ended when the passer reentered that lane. Data were collected under light flow conditions and no passes "hurried" due to oncoming traffic were included. The Brisbane passing time averages were uniformly shorter than those for Columbia. The coefficients of variation in Brisbane were uniformly larger than those for Columbia.

Overtakings

Equation 1 was used to predict overtaking demand within groups (e.g., bikers passing bikers), and Equation 2 was used to predict overtaking demand between groups (e.g., bikers passing joggers) during the sixteen 15-min time intervals studied in Brisbane. During those intervals, bicycle volumes ranged from 1 to 16 with a mean of 5.9; jogger volumes ranged from 1 to 13 with a mean of 8.6; and hiker volumes ranged from 4 to 30 with a mean of 12.6. Table 3 shows a comparison of the total number of overtakings to those predicted by the theory expressed in the two equations. Hikers overtaking other hikers and joggers overtaking hikers were overpredicted. However the predicted values of the other four types of overtakings appear fairly close to the observed values. The correlation coefficient, r, between total actual overtakings to those predicted for each of the 16 time intervals was .79.

TABLE 2 Distributions of Time to Pass (seconds) for Each Contribution

Passing Statistics	H/H	J/H[a]	B/H	J/J	B/J	B/B
Columbia						
Mean	17.3	6.1	3.9	4.4	6.5	3.7
Median	16.8	5.7	3.6	4.3	6.4	3.6
Standard Deviation	4.3	1.7	1.3	0.5	1.2	1.3
Coeff. of Variation	0.25	0.28	0.32	0.11	0.19	0.35
Minimum	10.6	3.6	1.8	3.6	4.8	2.2
Maximum	24.9	8.2	6.0	5.0	8.2	5.6
Count	8	7	11	5	9	9
Brisbane						
Mean	9.7	2.8	1.9	3.7	2.1	2.6
Median	7.8	2.4	1.7	2.6	1.9	1.9
Standard Deviation	5.1	1.4	0.94	3.5	0.74	2.0
Coeff. of Variation	0.52	0.50	0.50	0.96	0.36	0.75
Minimum	4.8	1.1	0.53	1.0	0.98	0.91
Maximum	19.5	8.4	5.2	12.1	4.1	5.5
Count	7	82	82	8	22	5

[a] The slash denotes who overtakes whom (e.g., J/H means jogger overtakes hiker).

Delayed Overtakings

A formulation adapted from work by Glennon (*5*) for passing conflicts on two-lane highways was used to predict potential conflicts, which would be expected to lead to delayed overtakings. The probability of an oncoming vehicle being in conflict with an overtaking vehicle is based on Poisson (random) arrivals of vehicles at a point. The probability of a conflict increases with the flow rate from the opposing direction and the time period required to complete the overtaking.

$$P(A) = 1 - P(0) = 1 - e^{-Vt/3600} \qquad (3)$$

where

$P(A)$ = probability of a passing vehicle encountering a conflict,
$P(0)$ = probability of a passing vehicle encountering no opposing vehicles,
V = flow rate from opposing direction (veh/hr),
t = time period in which opposing vehicle that would pass a particular point could cause a conflict (sec), and
3,600 = number of seconds in an hour.

The time t was based on the premise that no conflicting traffic should occupy the space to be used by the passer during the overtaking maneuver. This calculation involved the time required for the passing maneuver from Table 2 and the speeds from Table 1. For each of the six types of passes, $P(0)$ was determined separately for each potential type of conflicting traffic (hiker, biker, or jogger). The probability of no conflicts for each type of passer was then derived from the probability of no conflicting bike, no conflicting jogger, and no conflicting hiker. For example, for a biker to pass a jogger during one 15-minute increment, the probabilities of no oncoming bikers, joggers, or hikers were 0.986, 0.946, and 0.918, respectively. The probability of no conflicting traffic when a biker wished to pass a jogger was, therefore, $0.986 \times 0.946 \times 0.918 = 0.856$. The probability of a conflict (when a biker wished to pass a jogger during that 15-minute interval) was $1 - 0.856 = 0.144$, or 14.4 percent. The probabilities of conflicts during the 16 measurement periods are summarized in the upper section of Table 4.

The lower section of Table 4 shows the results for the 16 observation periods. As was the situation with passing demand, hikers

TABLE 3 Comparison of Theoretical Overtaking Demand to Observed Overtaking

	B/B	J/J	H/H	B/J	B/H	J/H	Sum
Theory	6.6	9.5	60.6	28.6	161.1	166.2	432.6
Actual	8	10	11	33	140	92	294

TABLE 4 Passing Conflicts

Probabilities of Passing Conflicts During 15-Minute Intervals (%)							
	B/B	J/J	H/H	B/J	B/H	J/H	Sum
mean	23.8	23.4	38.0	19.2	17.6	18.3	-
maximum	36.9	35.4	53.1	30.1	27.8	28.2	-
minimum	12.2	12.2	21.9	9.6	8.8	9.4	-
Comparison of Theoretical Overtaking Conflicts to Delayed Passes Observed							
theory	1.7	2.0	23.0	5.4	30.5	28.8	91.4
actual	4	2	0	7	34	5	52

passing hikers and joggers passing hikers were cases of overprediction. This could be expected because the theoretical overtaking conflicts equaled the number of desired overtakings multiplied by the probability of a conflict. Also, once again, the other four types of overtakings appear to be predicted reasonably well. The correlation coefficient, *r,* between delayed passes and predicted conflicts for each of the 16 time intervals was .82.

CONCLUSIONS

The objectives of the field study were to describe trail flow characteristics and to compare estimates of desired overtakings and potential conflicts with measured values of overtaking frequency and delayed overtakings. In comparing the two trails, mean speeds of the three types of traffic were fairly close to one another, but the standard deviation of jogger and biker speeds were much higher in Columbia. The recorded biking speeds of 5.95 and 5.76 m/sec were somewhat higher than that used in the Dutch manual (5.0 m/sec). The standard deviations of biking speeds (2.10 m/sec in Columbia and 1.33 m/sec in Brisbane) were much higher than the standard deviation of biking speeds used in the Dutch manual (0.83). Passing demand within a group such as bicycles is directly proportional to the standard deviation of speed and inversely proportional to mean speed. Therefore, the Dutch manual yields higher allowable volumes for a given LOS than would be the case if speed characteristics like those in Columbia and Brisbane were used.

In general, the equations to predict passing demand performed reasonably well. Estimates of hikers passing hikers and joggers passing hikers were high when compared with the observed values, but the other four estimates were quite close. Thus, the results tend to support the framework developed by Botma for bikers passing bikers and bikers passing pedestrians. Interestingly, Botma assumes that pedestrians seldom overtake other pedestrians and, therefore, does not include these overtakings in his approach. The low number of these overtakings in the data tends to indicate that this assumption may not be inappropriate.

Estimates of the probabilities of overtaking conflicts ranged from 9.4 percent to 38 percent for the study periods. Estimates of passing conflicts for hikers passing hikers and joggers passing hikers were high when compared with the observed values of delayed passes. Since the actual number of passes for these two cases was much lower than predicted, one could expect that the estimates of passing conflicts would also be high. The estimates of passing conflicts for the other four passing conditions appeared to be reasonably close to the number of observed delayed passes.

The Botma approach was the only one found in the literature to predict flow characteristics on shared-use trails. The results indicate that the Botma approach yields reasonable results for the range of flow conditions studied here. The two trails in this study had significantly higher standard deviations of biking speeds than those used by Botma. If one uses measured speed characteristics, the approach used to predict passing demand should yield accurate results.

The Columbia trail was primarily recreational and unpaved, whereas the Brisbane trail served both recreational and commuting purposes. It is expected that other trails may serve much different mixes of trip purposes and might, therefore, exhibit significantly different speed and overtaking characteristics. For that reason, much could be learned from a study of other trails with different mixes of trip purposes. The authors understand that some paved trails have significant use by in-line skaters. A more comprehensive study could address the impact of this fourth mode on shared-trail operation.

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