Field observations of factors influencing walking speeds

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This study measures pedestrian walking speeds in New Zealand to estimate the influences of mean walking speeds as these concern urban planning and pedestrian facility design. Research was conducted using field observations of walking speeds under different conditions: gradient and urban/rural townships. The data show complex interrelationships between environment, personal characteristics of pedestrian and physical factors. Mean walking speeds between 70-95 m/min are observed. These results do not support the ideal that walking speeds are indicative of pace of life. Rather, walking speeds are proposed to be an indicator of the environment's "walkability" as walking speeds that closely reflect that of the mean population are key to the successful design of pedestrian facilities.

1. Introduction

This paper examines mean walking speeds for the purpose of uptake by urban designers and engineers in planning pedestrian and transit facilities, and to benefit those examining walking as a mode choice. The promotion of walking as a mode choice is key to central governments due to the increased pressure on transit systems, environmental concerns and creating sustainable transit systems (Office of the Minister of Transport, 2006).

Researchers have measured pedestrian walking speeds for the purpose of planning pedestrian facilities and assessing facility performance, and to examine pace of life. Studies examining walking speeds for pedestrian facilities have focused primarily on pedestrian flow characteristics in urban setting such as sidewalks, footbridges, shopping centres (Polus *et al.* 1983; Morrall *et al.* 1991; Lam *et al.* 1995; Virkler, 1998; Lam and Cheung, 2000; Pachi and Ji, 2005) and transportation terminals (Fruin, 1971; Lam *et al.* 1995; Young, 1998; Lam and Cheung, 2000), and crossing times for crosswalk intersections (Lam *et al.* 1995; Knoblauch, *et al.* 1996; Fugger *et al.* 2000; Lam and Cheung, 2000; Bennett *et al.* 2001; Tarawneh, 2001). Common findings of these studies are that women walk slower than men and that people over 65 years of age walk slower than their younger counterparts. Across all these studies, pedestrian walking speeds varied from 98 m/min to 33m/min, with a mean speed of 80 m/min. For studies involving only observations of pedestrians away from crosswalks, a mean speed of 80 m/min was still obtained, with a maximum speed of 94 m/min.

"Walkability" is a term used to describe the quality and usability of a walking environment. Landis *et al.*, (2001) provide a review of the literature and summarise three major factors that influence walkability; 1) Sidewalk capacity, 2) Quality of the walking environment, and 3) Individual perceptions of safety/comfort. Walking infrastructure is also affected by the permeability of the environment (Allen, 2001). A highly permeable environment allows pedestrians to move unencumbered in all directions allowing for walking trips as the crow flies, compared with less permeable environments that require much less direct paths to be taken. As the environment becomes less permeable, the walkable radius decreases as the trips take more inefficient paths (Allen, 2001). These factors will not only have an effect of the performance of the walking infrastructure, but also the level to which it is adopted by the general public.

People adapt their travel behaviours according to time constraints, working to a “travel time-budget” (Mokhtarian and Chen, 2004). Marchetti (1994) reports that people tend to travel an average of one hour of travel per day. People adapt their transport decisions to maintain acceptable travel times. Newman and Kenworthy (2006) state that people are unlikely to walk more than 10 minutes to transit facilities, or 30 minutes to their destination. If this time budget is exceeded, they will likely opt for private vehicle transport.

Knowledge of pedestrian walking speeds is essential to accommodate time budgets. Urban planners take time-budgets into consideration when planning the placement of transit facilities. For example, a transit facility accessible to pedestrians within a 20 minute walk, assuming a walking speed of 80m per minute, has a catchment area of 8km^2. When walking speed is increased by 10%, the catchment area is increased by 20%. Therefore, inaccuracy in walking speed measures will have a large effect on the uptake of facilities, as too high an estimate of walking speeds will see people fall outside the catchment area. As there are no New Zealand data on walking speeds, the measure used in current design parameters are questionable.

Pace of life studies (Bornstein and Bornstein, 1976; Bornstein, 1979; Amato, 1983) have investigated the relationship between population size and walking speed, and report that pedestrians who live in cities with large populations have faster walking speeds than pedestrians who live in cities with small populations. Based upon data collected from numerous locations around the world, Bornstein and Bornstein (1976) provide evidence that there is a relationship between walking velocity and population size.

With these considerations recognised, pedestrian walking speeds in four New Zealand centres of differing populations were measured and the influence of a range of individual and environmental factors on walking speeds were investigated. These factors included gender, age, walking-surface-gradient, walking-for-purpose, baggage, children, shoe type, and distracting variables (i.e. “listening to music”, “using a cell phone” and “interacting with surroundings”).

Three sets of hypotheses are proposed that a) test consistency with outcomes from previous research conducted overseas; b) explore the influence of personal factors not examined in other studies and; c) investigate the influence of modern habits on walking speeds. From previous studies, it is expected that males will have a walking speed approximately 5m/min faster than females (Polus *et al.* 1983; Tarawneh, 2001) (H1). Pedestrians over the age of 65 will have a walking speed approximately 10m/min slower than the overall average walking speed (Knoblauch *et al.* 1996; Tarawneh, 2001) (H2). Walking speeds will be significantly slower on slopes greater than 3° (ITE Technical Council Committee, 1976) (H3). Contrary to Fruin (1979) and Young (1998) observations pedestrians walking with baggage will have slower walking speeds than pedestrians walking without baggage (H4). According to Knoblauch *et al.*, (1996) observations, pedestrians walking with walking others will be slower than pedestrians walking alone (H5). According to the pace of life theory (Bornstein and Bornstein, 1976; Bornstein

1979), pedestrians in the larger population centres will have a higher mean walking speed than those in the smaller, more rural centres (H6).

Personal factors considered to influence walking speed include walking for purpose, walking with children, shoe type and interacting with the environment. People walking for purpose, such as to catch transport or attend work, are proposed to have faster walking speeds than pedestrians without time constraints (H7). Adult pedestrians walking with young children, either by holding their hand, carrying them or pushing them in a pram, are expected to have slower walking speeds than pedestrians without children (H8). Pedestrians wearing flip-flops (i.e., a flat, backless sandal) and females wearing heeled shoes will have slower walking speeds than pedestrians wearing enclosed, flat shoes (H9). Pedestrians who are interacting with the environment by looking around will have slower walking speeds than pedestrians with their heads down or looking straight ahead (H10).

Modern habits, such as listening to music or using cell phones while walking are positively and negatively proposed to influence walking speed, respectively (H11 and H12, respectively).

2. Procedure

2.1 Site selection

Thirteen sites were chosen for their steady traffic flow and ability to be clearly monitored (Table 1). Certain sites were also selected for their slope, commuter traffic flow and variety of pedestrians.

Table 1. Description of selected sites

Site	*Location*	*N*	*City*	*Time of Day*	*Slope*
1	Albert Park	92	Auckland	12:00-12:30pm	Flat
2	Viaduct	100	Auckland	12:30-1:00pm	Flat
3	Great South Rd	53	Auckland	11:00-11:30am	Flat
4	Otahuhu	31	Auckland	12:00-12:30am	Flat
5	Wellesley St	78	Auckland	3:00-3:30pm	Slope
6	Queen St	94	Auckland	11:30am-12:00pm	Slope
7	Woodward Lane	145	Wellington	11:00-11:30am	Slope
8	Frank Kitts Park	88	Wellington	12:30-1:00pm	Flat
9	Central Station	547	Wellington	8:15-8:45am, 4:45-5:15pm	Flat
10	The Terrace	222	Wellington	11:00-11:30am	Slope
11	Parliament	237	Wellington	2:30-3:00pm	Slope
12	CBD	98	Palmerston North	11:00-11:30am	Flat
13	Bartholomew Rd	62	Levin	2:30-3:00pm	Flat

2.2 Materials

At each location a 5m section on the walkway was selected using 'natural' markers (e.g. edges of driveway, paving breaks) or marked with chalk. On sloped walkways, gradient was also measured. At each location, pedestrian movement was recorded for 30mins using a video camera positioned adjacent (or oblique, depending on environmental restrictions) to the observed section of walkway placed surreptitiously to avoid attracting the attention of pedestrians.

Walking speed was calculated from the frame where the pedestrian's body was centred on or over the first (entry) mark to the frame where the pedestrian's body was centred on or over the second (exit) mark. Pedestrians were chosen for analysis only if their movement did not appear to be obstructed by surrounding pedestrians and they did not have a walking impediment such as a walking cane or physical handicap. In addition to walking speed; gender, baggage type/amount, presence of children, shoe type, headphone usage, cell phone usage and looking around behaviours were coded, and age was estimated.

Reliability for walking speed and other factors was assessed by having an independent viewer observe 20 pedestrians from two different locations. Pearson's *r* was used to determine inter-rater reliability for walking speed, with a resulting coefficient of 0.99. Spearman's rho coefficient of 0.61 was obtained for age. Cohen's kappa was used to determine the inter-rater reliability for the remaining variables. Values were acceptable (between 1 and 0.65), except for "looking around" which did not obtain a significant value due to the observers different interpretation of the variable.

3. Results

3.1 Sample comparison

Walking speeds of 1847 pedestrians were recorded. Observations were made in Auckland (n = 448), Wellington (n = 1239), Palmerston North (n = 98) and Levin (n = 62).Sample differences were examined amongst populations drawn from each city (under similar conditions, i.e. flat and without commuters, n = 519) to investigate whether differences observed were due to demographic differences or biased samples. The Auckland sample was over-represented by males, and the Levin sample over-represented by females, $\chi^2(3, 540) = 23.59$, $p<0.001$. Young adults (those aged 15 to 30, compared with adults, aged between 30 and 55) were over-represented in Auckland and under represented in Wellington, further adults were over-represented in Wellington and under-represented in Levin and Auckland, $\chi^2(6, 540) = 27.31$, $p<0.001$. There were no significant interaction effects between city and gender, $F(3, 517) = 0.276$, $p>0.05$, or city and age $F(6, 517) = 1.51$, $p>0.05$. Although there are demographic differences between the groups, the observed differences do not interact with location to explain the differences in the mean speeds.

3.2 Individual Factors

Individual factors (Table 2) were only compared for pedestrians walking on flat ground (n = 1071) to ensure comparability between groups. The mean walking speed of these pedestrians was 88 m/min. Males (M = 90m/min, SD = 14.58) were found to walk significantly faster than females (M = 86m/min, SD = 13.20), $t(1069) = 4.95$, $p<0.001$. A one-way Analysis of Variance (ANOVA) revealed a significant differences in walking speed between age groups, $F(3, 1067) = 7.22$, $p<0.001$. Scheffé post hoc comparisons indicated significant differences between pedestrians aged 15 to 30 years and over 55 years, and between 30 to 55 years and over 55 years ($p<0.001$).

Table 2. Descriptive statistics of walking speeds on flat ground in metres per minute for pedestrians and their individual characteristics

Influence		*N*	*Mean Speed m/min*	*SD m/min*
Total	Flat Locations	1071	88.08	14.04
Gender	Male	527	90.18	14.58
	Female	544	85.98	13.20
Age	Child (under 15)	12	82.70	14.53
	Young Adult (15 to 30yrs)	330	87.72	13.38
	Adult (30 to 55yrs)	635	89.22	13.74
	Older Person (over 55)	94	82.44	16.68
Commuting	Total	519	94.20	10.38
Children		40	71.34	13.14
Baggage	No baggage	234	85.61	15.17
	Carrying Bags	659	90.79	13.16
	Talking to other person	63	78.78	14.48
	Both	115	82.60	11.42
Shoe Type	Trainers	237	87.60	12.54
	Flip-flops	77	78.72	13.68
	Flat	532	91.26	12.84
	Heeled	121	89.22	10.44
Visible headphones		22	93.36	10.74
Using Cellphone		9	90.80	16.04
Looking around		85	77.94	17.70

Pedestrians presumed to be commuting to and from work (as observations were made at 8:00am and 5:00pm being typical travelling to work times), from and to a train station, had significantly higher walking speeds than other pedestrians $t(999) = 15.48$, $p<0.001$. No significant difference in walking speed was found between pedestrians travelling to the city from the terminal in the morning and pedestrians heading to the terminal from the city in the afternoon. Walking speed was found to significantly decrease with the presence of children $t(1069) = 7.90$, $p<0.001$. Differences in walking speeds amongst adults walking with children, carrying children and pushing prams were not significant, likely due to low sample sizes.

Baggage arrangements had a significant effect on walking speeds $F(3, 1067) = 27.56$, $p<0.001$. Scheffé post hoc analysis indicated pedestrians who carried baggage had a significantly higher walking speed than those who did not have any baggage, those talking to others, and people talking to others and carrying baggage, $p<0.001$. As commuters have a significantly higher walking speed and are significantly more likely to carry baggage than non-commuters, $t(1239) = 29.26$, $p<0.001$, they were removed from the analysis and pedestrians with baggage were no longer found to be significantly faster than the other baggage/talking to people combinations. Pedestrians talking to others and carrying baggage were found to be significantly slower than pedestrians without baggage $t(294) = 3.28$, $p<0.001$, and pedestrians carrying baggage $t(105) = 3.89$, $p<0.001$. No difference in speed was found between pedestrians carrying one or two bags.

Shoe type significantly affected walking speeds, $F(3, 963) = 21.08$, $p<0.001$, such that pedestrians wearing flip-flops were slower than those wearing other types of shoes, $p<0.001$. No significant difference in walking speed was found between women who wear heeled shoes and those who wear flat shoes or trainers.

Pedestrians who were actively observing their surrounding environment had significantly slower walking speeds (*M* = 77.94, *SD* = 17.70) than pedestrians who were not actively observing their surrounding environment (*M* = 88.94, SD = 17.67), *t*(92.42) = 5.62, *p*<0.001. This result, however, should be interpreted with caution due to the low inter-rater reliability for this variable.

There was no effect of listening to music (visibly seen wearing headphones, or ear buds), or using cell phones on walking speeds. This could be due to the relatively small sample of those wearing headphones (*n*=22) or using cell phones (*n*= 9).

3.3 Location Factors

Overall, there was a significant effect of gradient on walking speeds, *F*(4,1842) = 17.12, *p*<0.001, showing a roughly parabolic trend with walking speeds increasing an non-significant amount from 0° to 4°, increasing significantly from 4° to 5°, p<0.05, constant from 5° to 6°, and then decreasing significantly from 6° to 7°, p<0.05. Descriptive statistics are shown in Table 3.

Table 3. Descriptive statistics of walking speeds at various locations in metres per minute

Influence		*N*	*Mean* *m/min*	*SD* *m/min*
Gradient	< 2°	1071	88.08	14.04
	< 2° w/o commuters	524	82.29	14.55
	4°	94	82.62	11.82
	5°	315	91.8	13.32
	6°	222	91.8	13.14
	7°	145	83.58	13.56
Slope walking direction	Uphill	373	87.66	13.44
	Downhill	403	90.54	13.86
Town size	Auckland	276	77.92	13.68
	Wellington	88	89.17	15.42
	Palmerston North	98	87.89	13.86
	Levin	62	80.07	12.36

Whether the pedestrians walked uphill or downhill (collapsing across gradient) had a significant on walking speed, *F*(2, 1327) = 42.71, *p* <0.001, such that pedestrians walking uphill or downhill were significantly faster than those on the flat, *p* <0.001, and those walking downhill were significantly faster than walking uphill, *p* <0.001

Across similar conditions, i.e. flat ground and not including pedestrians walking for purpose, a significant difference in walking speed was observed between the cities of Auckland, Wellington, Palmerston North and Levin F(3, 548) = 25.22, p<0.001. Post hoc analysis indicated that Auckland and Levin pedestrians are significantly slower than pedestrians in Wellington and Palmerston North, p<0.05. A significant difference in walking speeds between locations within Auckland was also noted, *F*(3, 272) = 15.87, p<0.001.

To ensure that any walking speed differences between location were not attributable to demographic differences, several checks were performed, revealing that the Auckland sample had a significantly higher proportion of pedestrians wearing flip-flops, *F*(3, 1067) =

197.27, $p<0.001$, and pedestrians interacting with the environment (looking around), $F(3, 1067) = 11.30$, $p<0.001$, compared to the other 3 locations. Removing these cases from the analysis, along with pedestrians walking on a slope and commuters in Wellington, made no difference to the relationship between walking speed and population reported previously.

No significant interactions were found between personal factors and walking on slope.

3.4 Pace of life

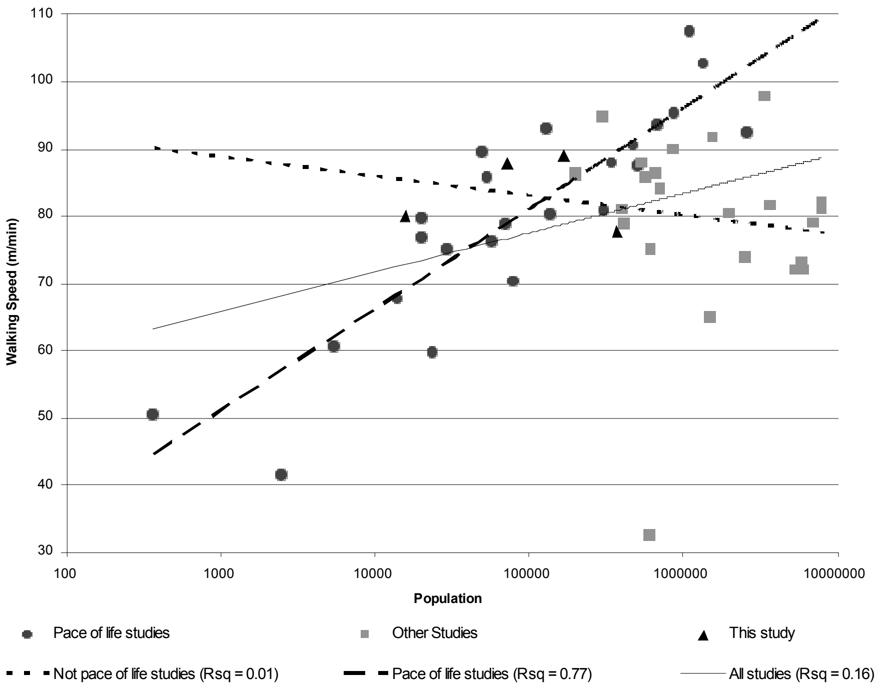
Mean walking speeds observed from 51 locations, encompassing results from this study, and further 22 studies are shown in Table 5. The mean walking speed across all the studies is 80.43 m/min ± 13.78. Figure 1 shows the mean walking speeds for each location against its population at the time of the study. The resulting regression equation is V = 2.55 log P + 48.12. Using only the data from pace of life studies, the regression equation is V = 6.51 log P + 6.38. The regression equation from non-pace of life studies is V = -1.21 log P + 97.044.

Table 4. Comparison of mean walking speeds

Author	*Country/City*	*Population*	*Mean speed (m/min)*
Hoel (1968)	USA, Pittsburgh	540,000	88
Older (1968)	UK, London	7,000,000	79
Fruin (1971)	USA, New York	7,900,000	81
Sleight (1972)	USA, New York	7,900,000	82
Bornstein & Bornstein (1976)	Czech Republic, Brno	342,000	88
Bornstein & Bornstein (1976)	Czech Republic, Prague	1,093,000	108
Bornstein & Bornstein (1976)	France, Corte	5,500	61
Bornstein & Bornstein (1976)	France, Bastia	49,400	90
Bornstein & Bornstein (1976)	Germany, Munich	1,340,000	103
Bornstein & Bornstein (1976)	Greece, Psychro	400	51
Bornstein & Bornstein (1976)	Greece, Itea	2,500	42
Bornstein & Bornstein (1976)	Greece, Iraklion	78,000	70
Bornstein & Bornstein (1976)	Greece, Athens	867,000	95
Bornstein & Bornstein (1976)	Israel, Safed	14,000	68
Bornstein & Bornstein (1976)	Israel, Dimona	23,500	60
Bornstein & Bornstein (1976)	Israel, Netanya	70,500	79
Bornstein & Bornstein (1976)	Israel, Jerusalem	304,500	81
Bornstein & Bornstein (1976)	USA, New Haven	138,000	80
Bornstein & Bornstein (1976)	USA, Brooklyn	2,602,000	92
Bornstein (1979)	Ireland, Galway	29,400	75
Bornstein (1979)	Ireland, Limerick	57,200	76
Bornstein (1979)	UK, Inverness	53,200	86
Bornstein (1979)	USA, Seattle	503,000	88
Bornstein (1979)	UK, Edinburgh	470,100	91
Bornstein (1979)	Ireland, Dublin	679,800	94
Amato (1983)	PNG, Port Moresby	130,000	93
Amato (1983)	PNG, Wewak	20,000	80
Amato (1983)	PNG, Mount Hagen	20,000	77
Polus, Schofer & Ushpiz (1983)	Israel, Haifa	410,000	79

Tanaboriboon, Hwa & Chor (1986)	Singapore, Singapore	2,500,000	74
Koushki (1988)	Saudi Arabia, Riyadh	1,500,000	65
Victor (1989)	India, Madras	5,338,000	72
Morrall, Ratnayake, & Seneviratne (1991)	Sri Lanka, Colombo	615,000	75
Morrall, Ratnayake, & Seneviratne (1991)	Canada, Calgary	708,500	84
Tanaboriboon & Guyano (1991)	Thailand, Bangkok	5,800,000	73
Lam, Morrall, & Ho (1995)	China, Hong Kong	6,095,000	72
Schmitt & Atzwanger (1995)	Austria, Vienna	1,550,000	92
Knoblauch, Pietrucha, & Nitzburg (1996)	USA, Washington DC	575,000	86
Knoblauch, Pietrucha, & Nitzburg (1996)	USA, Baltimore MD	660,000	86
Knoblauch, Pietrucha, & Nitzburg (1996)	USA, Richmond VA	200,000	86
Knoblauch, Pietrucha, & Nitzburg (1996)	USA, Buffalo, NY	300,000	95
Virkler (1998)	Australia, Brisbane	850,000	90
Fugger Jr., Randles, Stein, Whiting, & Gallagher (2000)	USA, Los Angeles	3,694,800	82
Bennett, Felton, & Akçelik (2001)	Australia, Melbourne	3,366,000	98
Taranwneh (2001)	Jordan, Greater Amman Area	2,000,000	80
Witte (2001)	Malta, Msida	600,000	33
Witte (2001)	USA, "Midwestern city"	200,000	86
Pachi & Ji (2005)	UK, Manchester	400,000	81
	New Zealand, Wellington	164,000	89
	New Zealand, Auckland	368,000	78
	New Zealand, Palmerston North	72,000	88
	New Zealand, Levin	15,500	80

Figure 1. Walking speeds as a function of population size



4. Discussion

The mean walking speeds of New Zealander's were collected in four locations with the purpose of investigating the effects of personal and location factors on walking speed, testing the relationship between population and pace of life, and examining how New Zealand walking speeds compare internationally as to determine their applicability to local urban planning.

The data collected represent the first New Zealand sample of walking speeds. Overall, the mean measured walking speed for flat locations is 88.08 m/min (± 14.04 m/min). When pedestrians walking for purpose are accounted for, the mean walking speed is 82.30 m/min (± 14.55 m/min), which is ~2m/min faster than the mean derived from the studies of other locations across the world.

The first set of hypotheses examined the consistency of results from this study with previous studies. In consensus with Polus *et al*., (1983) and Tarawneh (2001) men were found to walk faster than women by ~ 4m/min (H1). Older adults were found to be slower than their younger counterparts (Knoblauch *et al*. 1996; Tarawneh, 2001) but only by ~4m/min (H2). This faster speed relative to other studies is possibly due to the "older adult" age group including pedestrians aged 55 to 65 and may include some younger pedestrians as age was only estimated.

The effect of gradient on pedestrian's walking speeds was counterintuitive. Unsurprisingly, pedestrians walking speeds were faster downhill than they were uphill, however, they were faster uphill *and* downhill compared with flat (H3). Overall, the tendency was for walking speeds to increased as gradient does up to 6° and then decrease significantly (though the mean walking speed at 7° was not significantly different than on flat). This contradicts ITE's (1976) commonly cited report that as gradient increased walking speeds decreased. There are several reasons to be sceptical of the applicability of the ITE (1976) results. In their study they tested a military sample on treadmills which has little comparability to a dynamic free-flowing urban environment where pedestrians have actual goals and constraints on their time, making it difficult to justify its applicability to real world application especially in view of our contradictory results.

Fruin (1971) and Young's (1998) findings hold, as there was no significant difference in walking speed between pedestrians not carrying and carrying baggage (H4). Contrary to Knoblauch *et al*. (1996) there was no effect of pedestrians walking alone or with others (H5). However, pedestrians talking to others and carrying baggage were found to have significantly slower speeds than pedestrians without baggage and those carrying baggage.

Pedestrians from smaller, more rural centres were found to have faster walking speeds than pedestrians from the largest population centre (H6). There are differences in the demographic characteristics between the sample populations, however, these observed differences do not interact with location to explain the differences in mean speeds. Further discussion on this inconsistent finding with the pace of life theory follows.

As we were concerned with the influence of personal factors walking speed, factors such as walking for purpose, walking with children, shoe type and interacting with the environment were investigated. People walking for purpose/commuting were found to be faster than the average pedestrian (H7). Whether people were walking to or from work had no influence on their speeds potentially due to time constraints on both journeys e.g. work start time, train departure time. To assess the full commuter walking journey, pedestrians should also be observed walking to the train station before work, and from the station after work. Pedestrians walking with children were found to have a significantly slower walking speed than pedestrians without children (H8). Females who wear heeled shoes were not found to be significantly slower than their flat shoe wearing counterparts (H9). This may be a result of the way ‘heeled’ shoes were classified, i.e. shoes with too small a heel were being recorded. The higher the height of a heel, the more impact it may have on walking speed. Alternatively, it may be the case there is simply no effect of shoe height on women’s walking speed. Pedestrians wearing flip-flops were found to be slower walkers (H9). The walking speed of pedestrians actively observing their surrounding environment is significantly lower than those walking with their heads down or looking straight ahead (H10).

The influence of modern habits, such as listening to music and using cell phones on walking speed (H11 and H12, respectively) could not be determined due to the low number of pedestrians recorded undertaking either activity.

Walking speeds from 30 locations, including those from this study, were regressed against mean walking speeds to test Bornstein and Bornstein’s (1976) theory that pace of life varies as a function of population (more populated settlements exhibit higher mean walking speeds than less more populated settlements). No evidence was found to support a simple positive linear relationship between walking speed and pace of life. In fact, walking speed had a slightly negative relationship with increasing population size.

There are several possible reasons for why Bornstein and Bornstein’s (1976) finding is not supported. Walking speed is affected by observable environmental factors such as gradient and individual differences such as age and gender. It is also affected by less obvious environmental factors that influence the observation of mean walking speed. Walking speeds vary simply by the location in which the sample is drawn even when the sample is drawn at similar times using the same methods of observation. We propose that the mean observed walking speed is influenced, at the very least, by the availability of other transport modes and the suitability of the walking environment to accommodate walkers who represent the general population. Therefore, the observed mean walking speed in a large city with poor public transport and restricted private motor vehicle access (i.e. an environment that does not cater to all those who would use the facilities if they were adequate) would be observed as significantly slower than that of a smaller city with good public transport and open private motor vehicle access. In relation to this study, Auckland (major city, population 1 159 000) and Palmerston North (rural centre, population 72 000) are, respectively, examples of these types of cities. In the samples with higher walking speeds we may not be observing the walkers who the infrastructure does not support (i.e. slower walkers or walkers whose the trip cannot be made within their constraints such as a time budget) as they can elect alternatives such as public transport or private motor vehicles in smaller locations or locations provisioned with adequate public transport.

Alternatively, an observation of a “fast” mean walking speed may occur because of other non-observable factors such as fitness, motivation, and purpose of walking. Individual differences should not be observed in larger samples across arbitrary locations unless the provision of pedestrian services actually influences the population that uptakes walking. The effect of the latter can be inferred from locations selected for individual difference. We found that people walking to and from the train station (in our samples ‘commuters’) walk at a significantly faster pace than others. A combination of subtle environmental factors and individual difference probably influences the observations of different samples; to the extent that these can be quantified they reveal that previous observations of mean walking speeds are unlikely to adequately represent the true speed of walking in populations due to the small sample sizes.

It may well be that walking speed is related to a pace of life construct (whatever definition that might take), but the relationship is too complex for walking speeds to be used to as an indirect measure. Walking speeds may serve a more useful purpose as an indirect measure of the performance of the infrastructure supporting walking. In other words, deviations from the mean (that are not artefacts of the sampling method) are an indicator of the environment's ability to support the mean walking speed, that is, the environment's "walkability". For any comparison, more representative samples actual of walking speeds must be obtained.

5. Limitations

There were several limitations to this study. Several coded variables such as shoe type, age of pedestrian, wearing headphones etc. were often difficult to correctly identify due to the fixed camera angle and the direction pedestrians were walking in. The sample locations were chosen to obtain high sample numbers pedestrian numbers and other factors such as knowing people would be carrying baggage or there was a higher chance of children being present likely produced bias.

Observations were only made on weekdays, and generally at the same time of day. Pedestrians walking to and from the transportation terminal were only assumed to be walking for purpose to and from work and their speeds were not observed as a function of distance from the terminal. Walkway size and pedestrian density were considered, but kept constant. Studies that have examined the relationship between speed and density have found that speed decreases linearly with density. Although this study observed pedestrians that moved in an unrestricted fashion, pedestrian densities were markedly different between locations, with the commuter observation location being the most densely populated based on an overall impression.

One-off observations at a single location do not provide good grounds for urban planning, as they do not account for the variation of factors influencing a successful walking environment. Multiple observations at the same location might be undertaken to test the reliability of observation, as the results of one observation may not be truly representative of pedestrian walking speed at that location. To gain a more accurate understanding the nature of the walking population research examining non-observable factors that may influence walking speeds, such as motivation, fitness, willingness to walk and travel behaviours, could also be undertaken through the delivery of pedestrian interviews.

7. Conclusions

New Zealanders have a faster walking speed compared to the average derived from international studies. Personal and locational factors influence walking speed, must be taken into consideration when modelling pedestrian movements and where a "mean walking speed" is implicated in the placement and catchment areas of transit facilities. There is no simple relationship between walking speed and population size (cf. Bornstein and Bornstein, 1976). Walking speed is not an indicator of pace of life, instead it may be more useful as an indicator of the adequacy of the infrastructure supporting walking. The design of pedestrian facilities already recognises walkability and permeability, but a key indicator of performance is the alignment of observed mean walking speed with the mean walking speed that is representative of the general population.

8. References

ALLEN, A., 2001, Walking as a local transport modal choice in Adelaide. *World Transport Policy and Practice*, **7**, pp 44-51.

AMATO, P.R., 1983, The effects of urbanization on interpersonal behaviour: Field studies in Papua New Guinea. *Journal of Cross-Cultural Psychology* **14**, pp 353-367.

BENNETT, S., FELTON, A. and AKÇELIK, R. Pedestrian movement characteristics at signalised intersections. In *23rd Conference of Australian Institutes of Transport Research, Monash University, Melbourne, Australia, 10-12 December 2001*. Available online at: http://www.aatraffic.com/documents/PedsINTSignalisedXing(CAITR%202001)%20Paperv1.pdf (accessed April 2006)

BORNSTEIN, M.H. and BORNSTEIN, H.G., 1976, The pace of life. Nature **259**, pp 557-559

BORNSTEIN, M.H., 1979, The pace of life: Revisited. *International Journal of Psychology* **14**, pp 83-90.

FUGGER JR., T.F., RANDLES, B.C., STEIN, A.C., WHITING, W.C. and GALLAGHER, B., 2000, Analysis of Pedestrian Gait and Perception-Reaction at Signal-Controlled Crosswalk Intersections. In *Transportation Research Record 1705*, pp 20-25 (Washington D.C.: TRB, National Research Council).

FRUIN, J.J., 1971, *Pedestrian planning and design*. (New York: Metropolitan Association of Urban Designers and Environmental Planners).

HOEL, L.A., 1968, Pedestrian travel rates in central business district. *Traffic Engineering* **39**, pp10-13.

ITE TECHNICAL COUNCIL COMMITTEE 5-R, 1976, Characteristics and service requirements of pedestrians and pedestrian facilities. *Traffic Engineering* **46**, pp 34-45.

KOUSHKI, P.A., 1988, Walking characteristics in Central Riyadh, Saudi Arabia. *Journal of Transportation Engineering*, **114**, pp 735-744.

KNOBLAUCH, R.L., PIETRUCHA, M.T. and NITZBURG, M., 1996, Field Studies of Pedestrian Walking Speed and Start-Up Time. In *Transportation Research Record 1538*, pp 27-38 (Washington D.C.: TRB, National Research Council).

LAM, W.H.K. and CHEUNG, C., 2000, Pedestrian Speed/Flow Relationships for Walking Facilities in Hong Kong. *Journal of Transportation Engineering* **126**, pp 343-349.

LAM, W.H.K., MORRALL, J.F. and HO, H., 1995, Pedestrian Flow Characteristics in Hong Kong. In *Transportation Research Record 1487*, pp 56-62 (Washington D.C.: TRB, National Research Council)

LANDIS, B.W., VATTIKUTI, V.R., OTTENBURG, R.M., MCLEOD, D.S. AND GUTTENPLAN, M., 2001, Modeling the roadside environment: A pedestrian level of service. In *Transportation Research Record 1773,* pp 82-88 (Washington, D.C.: TRB, National Research Council)

MARCHETTI, C., 1994, Anthropological invariants in travel behaviour. *Technological Forecasting and Social Change* **47**, pp 75-88.

MOKHTARIAN, P.L. and CHEN, C., 2004, TTB or not TTB, that is the question: a review and analysis of the empirical literature on travel time (and money) budgets. *Transportation Research Part A* **38**, pp 643-675

MORRALL, J.F., RATNAYAKE, L.L. and SENEVIRATNE, P.N., 1991, Comparison of Central Business District Pedestrian Characteristics in Canada and Sri Lanka. In *Transportation Research Record 1294*, pp 57-61 (Washington D.C.: TRB, National Research Council)

NEWMAN, P. and KENWORTHY, J., 2006, Urban design to reduce automobile dependence. *Opolis: An International Journal of Suburban and Metropolitan Studies* **2**, pp 35-52

OFFICE OF THE MINISTER OF TRANSPORT, 2006, *Getting there – on foot, by cycle: Strategic implementation plan 2006-2009* (Wellington, NZ: The Office of the Minister of Transport).

OLDER, S.J., 1968, Movement of pedestrians on footways in shopping streets. *Traffic Engineering and Control* **10**, pp 160-163

PACHI, A. and JI, T., 2005, Frequency and velocity of people walking. *The Structural Engineer* **83**, pp 36-40.

POLUS, A., SCHOFER, J.L. and USHPIZ, A., 1983, Pedestrian flow and level of service. *Journal of Transportation Engineering* **109**, pp 46-56.

SCHMITT, A. and ATZWANGER, K., 1995, Walking fast – ranking high: A sociobiological perspective on pace. *Ethology and Sociobiology* **16,** pp 451-462.
SLEIGHT, R.B., 1972, The pedestrian. In *Human factors in highway traffic safety research*, T.W. Forbes (Ed.), pp 224-253 (New York: Wiley-Interscience).
TANABORIBOON, Y., HWA S.S. and CHOR, C.H., 1986, Pedestrian Characteristics study in Singapore, *Journal of Transportation Engineering* **112**, pp 229-235
TANABORIBOON, Y. and GUYANO, J., 1991, Analysis of Pedestrian Movement in Bangkok, Transportation Research Record 1372
TARAWNEH, M.S., 2001, Evaluation of pedestrian speed in Jordan with investigation of some contributing factors. *Journal of Safety Research* **32**, pp 229-236.
VICTOR, D.J., 1989, Pedestrian traffic management in Indian cities. In *5th World Conference on Transport Research,* July, Yokohama, Japan.
VIRKLER, M.R., 1998, Prediction and measurement of travel time along pedestrian routes. In *Transportation Research Record 1636*, pp 37-42 (Washington D.C.: TRB, National Research Council)
WITTE, A.L., 2001, Cross-cultural study of pace of life on two campuses. *Journal of Psychological Inquiry* **6**, pp 84-88.
YOUNG, S.B., 1998, Evaluation of pedestrian walking speeds in airport terminals. In *Transportation Research Record 1674*, pp 20-26 (Washington D.C.: TRB, National Research Council)