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Effect of Sidewalk Vendors on Pedestrian Walking Speed and Lateral Position: A Study in Addis Ababa, Ethopia

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Abstract

Street vendors use sidewalks to display goods and services. The reduction of sidewalk space by sidewalk vending activity forces pedestrians to take evasive action by changing walking speed and/or direction. Based on previous qualitative studies pedestrian evasive movements are related to pedestrian level of service and sharing carriageways. The aim of this paper was to investigate the effect of typical sidewalk vendor on average pedestrian walking speed and lateral position. The study used a field observation followed by a controlled walking experiment to study pedestrian behavior in the presence of typical sidewalk vendor. A univariate analysis of variance (ANOVA) of pedestrian trajectories, extracted from a walking experiment, showed that the average pedestrian lateral position and walking speed were significantly affected by the presence of a sidewalk vendor, pedestrian flow rate and the interaction effect of the two ($p<0.05$). The effect size also varied with the width of a vending stall and vendor's location relative to the pedestrian's desired trajectory. The results are consistent with previous observations and findings about pedestrian sidewalk behavior in the presence of sidewalk vendor. The findings may contribute in designing and or monitoring sidewalk vending activities.

Keywords: *Sidewalk vendors, Pedestrian trajectories, Walking speed, Lateral position*

1. Introduction

Street vending is an alternative means of livelihood for several low-income urban residents in global south [1], [2], [3], [4]. Street vendors provide affordable goods and services [5]. Vending stall placed at convenient locations also help create lively, active and engaging environment [1], [6]. On the other hand, vendors use sidewalks to store and sell consumable goods [7]. The space taken by sidewalk vending activities is an obstacles that reduce walking space and reduce pedestrian level of service (PLOS)[8]. Sidewalk vendors are also among risk factors that forces pedestrians share carriageways and increases pedestrian crash risk [9], [10]. Studies have used different approaches to understand the effect of sidewalk vendors on pedestrian sidewalk behavior.

The effective width approach have previously been used to study the effect of sidewalk vendors. In the United States of America Highway Capacity Manual (HCM), effective walkway width represents the width available for walking after subtracting the shy (building and traffic) distance and obstacles (e.g. vending stall) from the total walkway width [11].

A study conducted in Karachi, Pakistan has used a field observation using a checklist to describe how sidewalk encroachments (includes sidewalk vendors) had forced pedestrian share carriageways and the pedestrians in turn caused vehicles to deviate from initial trajectory to prevent crashes [12]. A study in Lima, Peru, used a multivariate model and showed that the number of sidewalk vendors is significantly correlated with pedestrian road crossing crash risk [9]. A study conducted Seoul, Korea used a multiple regression technique to identify contribution of number of pedestrians evasive actions from a video observation to perceived PLOS from field interview [13]. The study defined five categories of evasive movements that may vary based on pedestrian traffic flow [13]. The study used pedestrian evasive action as one indicator to describe perceived PLOS. However the application of this study to walkways with vendors is limited as the study considered only evasive action among pedestrians and excludes obstacles using the effective width approach. Pedestrian evasive action is a change in walking speed or lateral adjustment of walking path to maintain their personal space [13], [14]. However pedestrian evasive action could also be a result difference in pedestrian desired walking speed which for example lead to a move in lateral directions to overtake slow pedestrians [15-18].

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The main objective of this paper was to evaluate the effect of a typical sidewalk vendor (sidewalk vendor + vendor stall + one passing by customer) on average pedestrian's trajectory (walking speed and lateral position). This may allow to understand the effect of sidewalk vendors on pedestrian mobility and safety which could be a vital input for better street design and/or management.

2. Methods

This paper used the following methods to achieve the objectives:

- A field observation using a checklist to examine the characteristics of sidewalk hawkers in Addis Ababa, Ethiopia. The field observation was followed by a descriptive statistics to identify typical dimension and layout sidewalk vendor for a walking experiment.
- A walking experiment to study pedestrian walking behavior with and without presence of sidewalk vendors. Pedestrian trajectories extracted from controlled experiment were subjected to statistical analysis to analyze significance and effect size due to presence of sidewalk vendors.

2.1. Field Survey

Three major intersections ("Megenagna", "Mexico", "Tor Hailoch") in Addis Ababa, Ethiopia were selected for a field observation. The study sites were among locations of high sidewalk vending activity as stated by the city traffic management agency. Selected intersections are located along major public transport corridors of Addis Ababa that includes existing light rail transit (LRT) and proposed bus rapid transit (BRT) service. All intersections had a very high pedestrian activity specially during peak hours. Sidewalk vendors in general prefer locations and times of high pedestrian volume that improve vendors opportunity of transaction [7], [19], [20], [21], [22], [23]. The temporal variation may also be related to the fact that vendors are self-employed and they follow their own timetable [23]. This paper conducted a field survey was conducted on three separate days and on each day 4:30 PM to 6:30 PM. One checklist was used to observe one vendor. The checklist includes vendors service type, width of vending stall, relative location on walkway etc. The width a vending stall was estimated by counting the number of tiles. A single tile was a square with a dimension of 25cm.

2.2. Study ground for Walking experiment and participants

A walking experiment was used to collect pedestrian trajectories in the presence of typical sidewalk vendor. . The experiment ground layout includes an observation ground (3m*14m) with a vendor, vending stall and pedestrian interacting a vendor placed at the center (Figure 1). The layout allows a bidirectional pedestrian flow with pedestrians walking in direction 1 (D1) and direction 2 (D2) (Fig. 1). Three coordinators (number 5, 6 and 7 in Fig. 1) were trained to use a timer and a whistle to control the arrival rate of pedestrians.

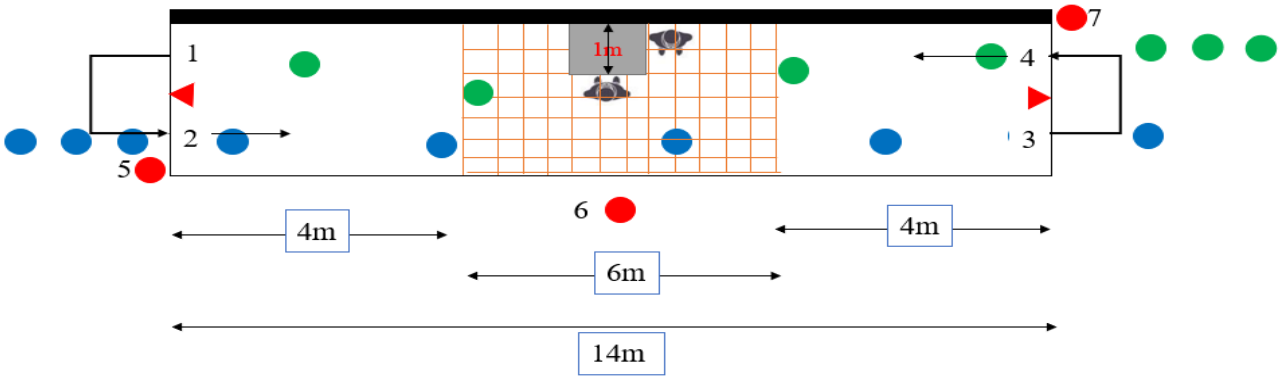


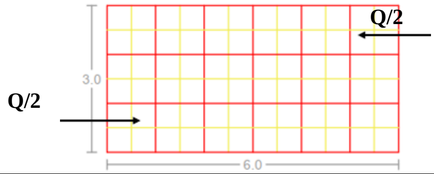
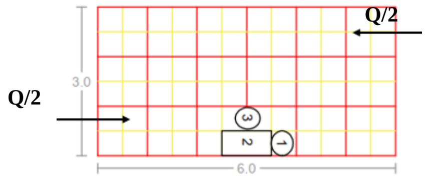
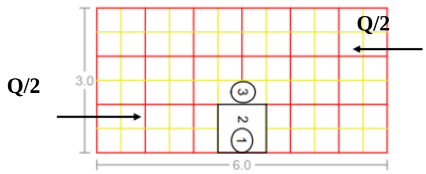
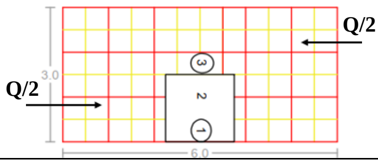
Fig. 1. Layout of a study ground for walking experiment

A total of 100 undergraduate university students (31 female and 69 male) took part in the experiment. Participants were given a participants information sheet and volunteers signed a free consent form. The sample size was estimated to have sufficient participants in queue and high flow rates from previous studies. The estimated capacity of walkway at PLOS E is 72-75 pedestrian/minute/meter [29]. After obtaining a permit, a study ground (inside a basketball court) was cleaned and marked at known spacing using colored tape. The marking was necessary to serve as a reference to calibrate the video recording. The use of observation ground and creating reference points (markings), lines (with tapes) or fixed object a procedure previously used by other researchers [31], [32].

2.3. Walking Scenarios

The field experiment was conducted on March 02, 2019 inside a basketball court located in Wolkite University, Ethiopia. The experiment started at 9:30 AM and continued till 11:30 AM. Participants were informed to keep walking as they normally would (similar to [16]). In order to observe pedestrian walking behavior at different flow states and different vending stall dimensions, 16 walking scenarios (matrix of 4 vendor types * 4 bidirectional flow rates) were conducted (Table 1). The number of scenarios was limited to 16 considering resource limitations and time required to conduct the experiment. A typical vending activity includes a vendor, a vending stall and one customer waiting for service. From Table 1, V0, V1, V2, and V3 represent a walkway without vendor activity, with a 0.5m, 1m and 1.5m wide vending stall respectively. These allows to see the effect of varying width of sidewalk vendor on pedestrian motion. The maximum width of the vending stall was limited to 1.5m because it represents 91% of observed sidewalk vending stalls from field observation (Table3). A bidirectional flow with directional split = 0.5 (equal flow in both directions) was considered. Four flow states Q1, Q2, Q3, and Q4 that represent a bidirectional pedestrian flow rate of 20, 30, 60 and 80 pedestrians per minute respectively were used. These allows to observe different interaction among pedestrians and sidewalk vendor at different flow states. A single walking scenario includes a combination of pedestrian flow and vendor dimension. For example, Q4V3 represents a bi-direction pedestrian arrival rate of 80pedestrian/minute (40pedestrian/minute/ direction) in the presence of a 1.5m wide vending activity.

Table 1. Matrix for walking scenarios considered for a walking experiment

		Bi directional pedestrian flow/minute			
	Symbol	Q1	Q2	Q3	Q4
	Flow/minute	20	30	60	80
	Headway (seconds) in one direction	6	4	2	1.5
V0 (0m No vendor activity (Reference case))		V0 Q1	V0 Q2	V0 Q3	V0 Q4
V1 (A vendor and its item took 0.5m width of walkway*1m)		V1 Q1	V1 Q2	V1 Q3	V1 Q4
V2 (A vendor and its item took 1m width of walkway*1m)		V2 Q1	V2 Q2	V2 Q3	V2 Q4
V3 (A vendor and its item took 1.5m width of walkway*1.5)		V3 Q1	V3 Q2	V3 Q3	V3 Q4

2.4. Extracting Pedestrian trajectories from video observations

The camera was first calibrated using T-calibration software. The result of T-calibration was satisfactory with a map error of 3-6cm on the entire study ground. Results of T-calibration served as an input for semi-automatic extraction of pedestrian trajectories using T-analyst software. A semi-automatic approach was used to extract headways, and trajectories from a video recording of a controlled experiment. Using a semi-automatic data extraction approach by manual annotation and software extraction of trajectory is already used in previous studies [31], [30], [31]. A box was placed around each pedestrian which was traced every three frames in which there are 30 frames per second (Figure 3). Curved interpolation was then used to smooth and connect between traced frames. The algorithms for data to extract the real world coordinate of each pedestrian from video surveys are based on the projection techniques described in [18].

2.5. Analysis of pedestrian trajectories

From a controlled experiment, lateral position and point speed data of 31 pedestrians was prepared for two directions, four flow states, four vendor types and 33 measurement points along the length of the observation area. The measurement points are x=0.5m, 0.6m, 0.8m, 1m….. continues up to 7m length at the 0.2m interval. For example point 14 represents 3m measure longitudinally inside observation ground. A statistical analysis was then conducted to evaluate the effect of a sidewalk vendor on average pedestrian walking speed and lateral position. The study had two dependent variables; pedestrian walking speed, and lateral position. The independent variables were the pedestrian arrival rate and vendor type. A univariate analysis of variance (ANOVA) for one direction and one parameter (lateral position or speed) was conducted. A post-hoc test for factors that have a significant interaction effect on pedestrian lateral position and speed was also conducted to quantify the effect size.

3. Results

3.1 Field Observations

3.1.1. Characteristics of sidewalk vendors

A total of 1,310 vendors were observed at three intersections. A significant amount of walkway space around intersections was occupied by vending stalls, vendors and their customers. Vendors were more frequent between public transport stations and around pedestrian crossings. Vendors frequency declined significantly at midblock that have lower pedestrian volume. Temporal variation indicates a rise in the number of walkway vendors during the afternoon peak hour (3:30 PM to 7:30 PM). A checklist was used to observe basic characteristics of sidewalk vendors in Addis Ababa. From field observation,

vendors selling goods (second-hand garments, bags, shoes, umbrella, tools, utensils, crafts etc.) and shoeshine service providers were the most frequent(60%). More than one-third (38%) of walkway vendors had a relatively stationary vending stall. Roughly one-fifth (23%) of all observed vendors were semi-formal with a stationery and semi-permanent shade/stand (Table 2). The remaining (58%) of walkway vendors were mobile that frequently change location looking for customers and/or avoiding enforcement officers. Male vendors represent roughly three-quarter (75%) of observed street vendors at observed intersections. Female vendors mostly sell fast food and vegetables and were relatively stationary. Whereas males were engaged in almost all types of vending activities.
The observed method of displaying items at observed intersections of Addis Ababa was highly random. Street vendors seem to use anything available to display goods and services on walkways, carriageways and off-street land use. Vendors mostly used plastic mats ("Madaberiya/Shera") to display goods, bags & tables to store fast food & drink, wheelbarrows to display fruits. Some street vendors carried their item on shoulder or head ("Suk Bederete/ Mefakiya"). Semi-Formal kiosks ("Arkebe Suk") were also used to display goods with a formal/informal approval from the local administration. The frontage zone was the most frequently(56%) used part of sidewalks. Other locations used by street vendors include pedestrian bridges, underpass, open public and/or private spaces. Most(72%) vendors displayed their items by standing behind their vending stall. A vending stall width of 0.5m and 1.5m were the most common (31% each). A vending stall width ≤1m was mainly used by vendors selling second-hand clothes, vegetables, fruits, shoes, etc. While a vending stall width of 1.5m was common for Shoeshine and fast food service providers. Only 9% of observed vendors had a vending stall width between 2 and 3m. These vendors were mainly micro-enterprises that have a formal or semi-formal permits from city traffic management agency, trade bureau or local administration.
This study has used sidewalk vendor lay out type B (Fig. 2) for controlled experiment. Layout type A (vendor behind vending stall) is the most frequent (72%) as compared with type B (Vendor standing next to vending stall) (11%). However standing behind a vending stall is less efficient as compared to standing adjacent because it encroaches more walkway width

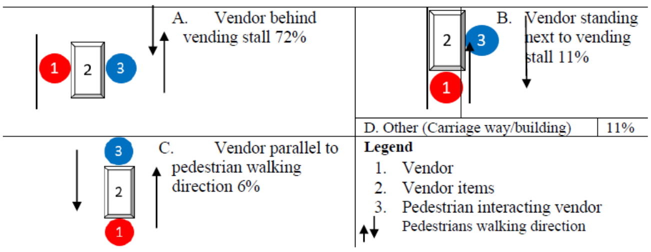


Fig. 2. Vending Layout types

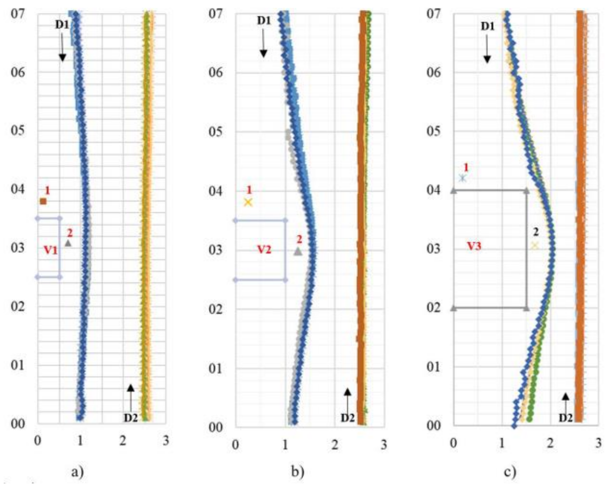
3.2 Walking experiment

3.2.1. Pedestrian desired trajectories without sidewalk vendor activities

Based on data extracted from a walking experiment, pedestrian trajectories in the absence of vending activity were plotted to identify pedestrian desired path. Accordingly, the average desired trajectory had a shy distance of 0.7m from the building side and 0.45m from the free side.

3.2.2. Pedestrian desired trajectories in the presence of sidewalk vendors

Average pedestrian trajectories in the presence of 0.5m, 1m and 1.5m wide sidewalk vendors (V1, V2, and V3 respectively) was also plotted. Only pedestrians walking in direction 1 had a desired trajectory that conflicts with the location of the vendor. Pedestrians in direction 1(D1) showed a large deviation from the desired trajectory(Fig. 3c). The larger the vendor size, the bigger was the lateral deviation with its maximum at the center of the sidewalk vendor (Fig. 3). While those pedestrians in direction 2(D2) had secondary effect of sidewalk vendor from interaction with pedestrians that are directly affected by a sidewalk vendor.



Legend: D1 & D2 = direction 1 and direction 2 respectively, 1 = A vendor, 2 = A pedestrian interacting a vendor, V1, V2, V3 = 0.5m, 1m and 1.5m wide vending stall respectively

Fig. 3. Pedestrian desired trajectory in the presence of sidewalk vendors (a)V1, (b) V2, (c) V3

3.2.3 Walking speed with and without sidewalk vendors

The average walking speed with and without sidewalk vendors was also plotted (Fig. 4). The horizontal axis represents 31 measurement points (x=0.5m, 0.6m, 0.8m, 1m….. 7m) and the vertical axis represent pedestrian walking speed (m/sec). Pedestrians walking in direction 2 gradually lowered their average speed from entry to exit (Fig. 6b). The effect on pedestrian walking in direction 1 varied with width of vending stall. Under case V1, pedestrians walking speed in direction 1 was less influenced by presence of sidewalk vendor. Whereas under V2 and V3 pedestrians lowered their walking speed as they approach the center point of vendor activity (point 14=3m) and then accelerated after passing the sidewalk vendor (Fig. 4a).

3.2.4 **Significance of effect of sidewalk vendor on walking speed and lateral position**

A statistical analysis was conducted on pedestrian trajectories extracted from a walking experiment. Univariate analysis of variance (ANOVA) was conducted for one direction and one parameter (lateral speed or speed) using 31 data elements. As a result, the presence of a vendor activity, variation of pedestrian flow and the interaction effect of the two had a significant effect on pedestrian lateral position and walking speed at 0.05

level (Table 2 & 3). A post hoc analysis was conducted for the interaction effect of vendor*point to quantify the magnitude of difference in lateral position. Accordingly, the mean lateral position varied across different measurements points significantly for a given vendor type. In direction 1, V1, V2 and V3 resulted in maximum lateral deviation of 0.557m*, 0.969m* and 1.447m* as compared to V0 (Table 4). For pedestrian walking in direction 2, V1 did not have a significant effect, while V2 and V3 resulted in lateral deviation to the right by 0.046m* and 0.125m*respectively (Table 4). A pairwise comparison indicates that the presence of vendor activity had little effect on average walking speed of pedestrians walking in direction 2. Vendor type 1 (V1) seems to have little effect on pedestrian speed in direction 1 and it has actually increased pedestrian walking speed in direction 2 up to 0.047m/sec* (Table 5). A pedestrian walking in direction 1 reduced their walking speed by 0.151m/sec* and 0.113m/sec under V2 and V3 respectively (Table 5).

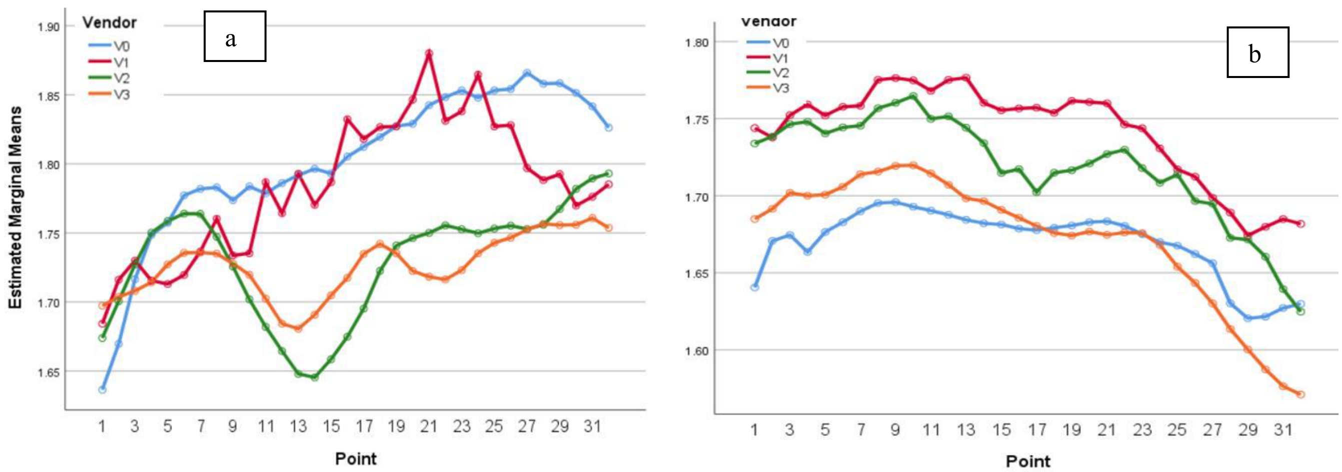


Fig. 6. Average walking speed with and without sidewalk vendors (a) direction 1, (b) direction 2

Table 2: Effect of presence of vendor on pedestrian lateral position in direction 1 and 2

		Vendor	Flow	Point	Vendor*Flow	Vendor*Point	Flow*Point	Vendor*Flow* Point
ANOVA Lateral position in direction 1 (D1)	Hypothesis d.f	2.49	2.89	2.39	5.49	5.47	4.75	7.58
	Error d.f	74,70	86.88	71.90	164.76	164.12	142.65	227.44
	F	3714	8.47	3145.25	5.49	621.60	8.739	5.14
	p	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ANOVA Lateral position direction 2 (D2)	Hypothesis d.f	3	3	3	5	4	5	5
	Error d.f	79	83	97	147	131	138	138
	F	41	22	77	5	5	4	2
	p	0.000	0.000	0.000	0.001	0.000	0.005	0.062

Table 3: Effect of presence of vendor on pedestrian walking speed in direction 1 and 2

		Vendor	Flow	Point	Vendor*Flow	Vendor*Point	Flow*Point	Vendor*Flow* Point
ANOVA Walking speed in direction 1 (D1)	Hypothesis d.f	3	2	6	6	10	10	14
	Error d.f	75	73	167	176	313	310	417
	F	14	6	69	4	15	5	4
	p	0.000	0.002	0.000	0.001	0.000	0.005	0.062
ANOVA (walking speed) in direction 2 (D2)	Hypothesis d.f	2	2	5	2	7	8	8
	Error d.f	48	54	157	51	205	235	253
	F	5	9	81	22	3	2	3
	p	0.013	0.001	0.000	0.001	0.016	0.037	0.003

Table 4: Effect size of type of vendor size on pedestrian lateral position for a given measurement point in direction 1 and 2.

Measurement point (ym)	F(Hypothesis d.f, Error d.f,), p		Effect size of V1 w.r.t V0 (m)		Effect size of V2 w.r.t V0 (m)		Effect size of V3 w.r.t V0 (m)	
	D1	D2	D1	D2	D1	D2	D1	D2
29 (6.0m)	714(2,71), p=0.000*	21(3,81), p=0.000*	0.379*	---	0.478*	0.036*	0.673*	0.084*
24 (5.0m)	1197(2,74), p=0.000*	19(3,77), p=0.000*	0.468*	---	0.617*	---	0.908*	0.090*
19 (4.0m)	4082(2,78), p=0.000*	36(3,83), p=0.000*	0.538*	---	0.815*	0.028*	1.250*	0.110*

14 (3.0m)	9404(2,62), p=0.000*	57(3,79), p=0.000*	0.557*	---	0.969*	0.046*	1.447*	0.125*
9 (2.0m)	6549(2,65), p=0.000*	60(3,77), p=0.000*	0.506*	---	0.846*	0.050*	1.291*	0.126*
4 (1.0m)	2496(2,59), p=0.000*	50(3,81), p=0.000*	0.436*	---	0.690*	0.046*	1.037*	0.111*
1 (0.5m)	1744(2,59), p=0.000*	43(3,84), p=0.000*	0.405*		0.604*	0.038*	0.930*	0.099*

Table 5: Effect of type of vendor size on pedestrian walking speed for a given measurement point in direction 1

Measurement point (ym)	F(Hypothesis d.f, Error d.f,), p		Effect size of V1 w.r.t V0 (m/sec)		Effect size of V2 w.r.t V0 (m/sec)		Effect size of V3 w.r.t V0 (m/sec)	
	D1	D2	D1	D2	D1	D2	D1	D2
29 (6.0m)	10(2,73), p=0.000*	5(2,48), p=0.013*	-0.066*	---	-0.091*	---	-0.103*	---
24 (5.0m)	26(3,78), p=0.000*	3(2,61), p=0.047*	---	0.061*	-0.098*	---	-0.113*	---
19 (4.0m)	15(3,82), p=0.000*	6(2,44), p=0.008*	---	0.081*	-0.087*	---	-0.092*	---
14 (3.0m)	30(3,80), p=0.000*	5(2,49), p=0.018*	---	0.078*	-0.151*	---	-0.106*	---
9 (2.0m)	3(2,74), p=0.033*	5(2,59), p=0.011*	---	0.080*	-0.048*	0.064*	-0.046*	---
4 (1.0m)	3(2,62), p=0.062	7(2,56), p=0.003*	---	0.096*	---	0.085*	---	---

4. Discussion

The main objective of this study was to evaluate the effect of a typical sidewalk vendor on pedestrian lateral position and walking speed. This paper used a field observation to study the characteristics of sidewalk vendors and a walking experiment and statistical analysis to investigate pedestrian walking speed and lateral position in the presence of typical sidewalk vendor from field observation.

Results of walking experiment showed that the presence of sidewalk vendor, pedestrian flow rate and the interaction effect of the two had a significant effect on the pedestrian lateral deviation and walking speed ($p< 0.05$). This is similar to previous finding that, the presence of obstacles followed by opposing pedestrian flow rate as two the most important attributes that influence pedestrian sidewalk behavior [10]. However the findings of [10] are based on a conjoint analyses of a field observation and pedestrian stated preference on ranking important attributes that influence their sidewalk behavior. The results are also expected as the walking behavior of a pedestrian is influenced by presence of other pedestrians, obstacles and psychological forces [32]. The presence of a sidewalk vendor had a direct effect on lateral deviation of pedestrians whose desired trajectory conflicts with the location of a vending stall and an indirect effect on other pedestrians. Pedestrian has to deviate laterally to avoid sidewalk vendor and its customer while maintaining a personal space from opposing pedestrians. The implication of this finding could be a decline in pedestrian perceived PLOS with presence of sidewalk vendor because pedestrian perceived PLOS decline in with an increase in number of evasive actions by a pedestrian [13]. The result also supports previous recommendations to leave a continuous clear pedestrian path while allocating a vending stall [28].

The size of lateral deviation of a pedestrian from its desired trajectory has increased in conjunction with an increase in width of vending stall. The presence of a customer interacting sidewalk vendor also contributes to pedestrian evasive action. Depending of available width of for walking, it is evident that some pedestrians may share carriageways to avoid sidewalk vendors, their customers and/or other pedestrians in opposite direction. This may explain observation previous studies regarding pedestrian share carriageways creating conflict with vehicles related to presence of sidewalk encroachments [12], [10].

All in all this paper showed only how the effect of single sidewalk vendor on pedestrian walking speed and lateral position which based on previous studies can be related to lower pedestrian perceived PLOS and pedestrians sharing carriageways. The findings of this study may contribute to design and management or studies on better street management considering pedestrians sidewalk behavior in the presence of sidewalk vendors.

5. Conclusions

This paper has quantitatively analyzed the relationship between sidewalk vendors and an average pedestrian walking speed and lateral position based on a walking experiment. In most cases, the presence of sidewalk vendor along with pedestrian flow had caused pedestrians change path and reduce walking speed. However the effect size varies depending on width of vending stall and pedestrian volume. Understanding pedestrian walking behavior in the presence of sidewalk vendors could be an essential input for better street design that accommodates the diverse needs of cities.

Nomenclature

D1	Direction 1
D2	Direction 2
d.f.	Degree of freedom
Q1	A bidirectional pedestrian flow rate of 20 pedestrian per minute with directional split=50%
Q2	A bidirectional pedestrian flow rate of 30 pedestrian per minute with directional split=50%

Q3	A bidirectional pedestrian flow rate of 60 pedestrian per minute with directional split=50%
Q4	A bidirectional pedestrian flow rate of 80 pedestrian per minute with directional split=50%
V0	A side walk without any vendor encroachment
V1	A side walk with a vendor having 0.5m wide and 1.0m long vending stall
V2	A side walk with a vendor having 1.0m wide and 1.0m long vending stall
V3	A side walk with a vendor having 1.5m wide and 1.5m long vending stall
w.r.t.	With respect to

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