Study on Pedestrian's Speed and Density under the Mid-low Density: Comparison of Pedestrian Behavior on the Station Square between Chiba, Japan and Shanghai, China

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Abstract

Context

The correlation between pedestrian's speed and density is a key point in walking space research. In the field of walking space, there are massive investigations about the correlation between speed and density under the high pedestrian density. Under the mid-low density condition, the question about the correlation between pedestrian's speed and density is not a hot topic in previous researches.

In fact, pedestrians are under the mid-low density condition at all time. And the station square is also a place where there are many pedestrians. Additionally, much attention has been attracted to pedestrian-oriented planning and the cultural implications of place-making in urban planning. Therefore it is necessary to discuss the correlation between speed and density under the mid-low density and compare pedestrian behavior on the station square between Japan and China in order to clarify the different characteristics of pedestrian behavior in dissimilar cultural contexts.

Method

We took the north square of JR Nishi-Chiba Station in Chiba, Japan and the fourth square of Dapuqiao Station in Shanghai, China as two examples. These two squares both have steps and flat. We took videos for one hour in spare time and rush time on these two station squares. We then investigated the situation of pedestrian streams in

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the spare time and in the rush time. By images of these videos, we drew pedestrians' pathways from parts of the videos. So we could get the information of speed, density and shortcut behavior by these pedestrians' pathways.

Statistics & Analysis

From the statistics of data, we could describe the characteristics of speed and density during different periods on the two squares. After the statistic of speed and density, we calculated separately the correlation between pedestrian's speed and density on the steps and on the flat in the spare time and in the rush time.

Conclusion

After the analysis, the characteristics of pedestrian behavior were as follows:

General characteristics on the two squares: the speed is slow and the density is low in the spare time; the speed is fast and the density is high in the rush time. The speed on the steps is slower than on the flat. Under the mid-low density walking space, the correlation between speed and density is weakly positive correlation. It is different from the correlation under the high density walking space. In other words, a certain degree of density can make pedestrians speed up.

Different characteristics on the two squares: pedestrian's speed on the square of Dapuqiao Station is slower than JR Nishi-Chiba Station. Shortcut behavior on the square of Dapuqiao Station is more obvious than JR Nishi-Chiba Station. These results suggest that pedestrians in some parts of China adopt shortcut rather than fast walking for quickly reaching the destination, but pedestrians in some parts of Japan more adopt fast walking. These results are useful to create walking spaces which will be more suitable and effective for person's behavior in dissimilar cultural contexts.

Keyword

Density, Speed, Pedestrian, Station Square, Shortcut behavior

1.0 Context

The correlation between pedestrian's speed and density is a key point in walking space research.(Fruin, J.J., 1971; Pushkarev, Boris. and Zupan, Jeffrey. M., 1975) In the field of walking space, there are massive investigations about the correlation between speed and density under the high pedestrian density.

For studying the effect of the high density on the pedestrian, some researchers

divide pedestrian's density into 3 sections. In the section B and C: density > 1.1 p/m^2(person/m^2), it is taken as the high density section and pedestrian's walking is not free, the correlation between speed and density is negative.(Minegishi. Yoshikazu, 2008; Nishida Yoshihiro, 1985) But in the section A: 0.0 p/m^2 ~ 1.1 p/m^2, it is taken as the mid-low density section. In the section A, some research refer to the part of 0.5 p/m^2 ~ 1.1 p/m^2 , and the correlation between speed and density is considered negative or not obvious.(Morita Takao, 2004; Hirai Noriyuki, 1993)

Under the mid-low density condition, the question about the correlation between pedestrian's speed and density is not a hot topic in previous researches.

In fact, pedestrians are under the mid-low density condition at all time. And the station square is also a place where there are many pedestrians. Additionally, much attention has been attracted to pedestrian-oriented planning and the cultural implications of place-making in urban planning. Therefore it is necessary to discuss the correlation between speed and density under the mid-low density and compare pedestrian behavior on the station square between Japan and China in order to clarify the different characteristics of pedestrian behavior in dissimilar cultural contexts.

2.0 Purpose

This research will take the part of pedestrian density 0.0 p/m^2~0.35 p/m^2 as a condition object, and discuss the correlation between the pedestrian's speed and density on the flat and on the steps.(Nishida Yoshihiro, 1984)

3.0 Observation

We took the north square of JR Nishi-Chiba Station in Chiba, Japan and the fourth square of Dapuqiao Station in Shanghai, China as two examples. These two squares both have steps and flat. We took videos for one hour in spare time and rush time on these two station squares.

3.1 Observation in Japan

3.1.1 Place

JR Nishi-Chiba station north square is in Chiba, Japan. This square has a pure function of transportation. It makes the motivation of walking simple.This square is divided into two parts: flat and steps.(Figure 1, Figure 2)

Figure 1 JR Nishi-Chiba Station

Figure 2 JR Nishi-Chiba Station North Square

3.1.2 Observation time

2010/07/02 It is under the mid-low density condition.
12:30-13:30 spare time(lunch)
17:30-18:30 rush time(go home)

3.1.3 Tool

25mm wide-angle lens camera and timing device.

Figure 3 Dapuqiao Station

Figure 4 Dapuqiao Station Entrance 4 Square

3.2 Observation in China

3.2.1 Place

Dapuqiao Station Entrance 4 square is in Shanghai, China. It is a part of a circular plaza around the subway station. This square also has flat areas and steps.(Figure 3, Figure 4)

3.2.2 Observation time

2011/04/21 It is under the mid-low density condition.
12:00-13:00 spare time(lunch)
17:00-18:00 rush time(go home)

3.2.3 Tool

25mm wide-angle lens camera and timing device.

4.0 Comparison of pathways

We then investigated the situation of pedestrian streams in the spare time and in the rush time. By images of these videos, we drew pedestrians' pathways from parts of the videos. So we could get the information of speed, density and shortcut behavior by these pedestrians' pathways.

4.1 Pathways of JR Nishi-Chiba station square

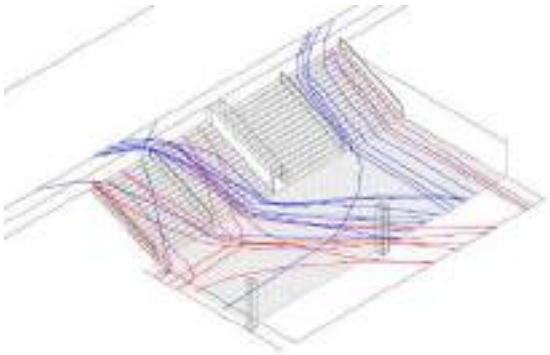

Figure 5 Pedestrians' Pathways on JR Nishi-Chiba Station Square (60s in spare time 12:30-13:30)

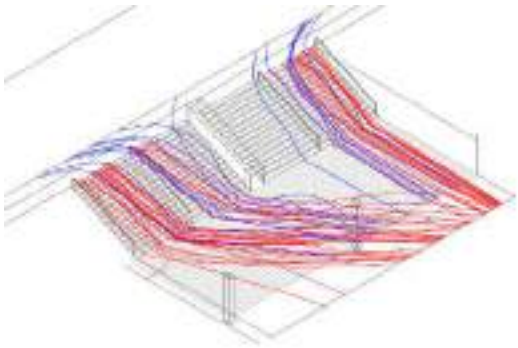

Figure 6 Pedestrians' Pathways on JR Nishi-Chiba Station Square (60s in rush time 17:30-18:30)

We took the videos of JR Nishi-Chiba station square for two periods: 12:30-13:30; 17:30-18:30. Then we chose 5 minutes rush time video from every period. We printed 60 pages of image for every minute video. Through these images, we can draw the pathways. Figure 5 and Figure 6 is pathways for one minute(60s) in spare time and in rush time. In these figures, blue lines are pathways of going up steps; red lines are pathways of going down steps. We find that there are more people going up steps in 12:30-13:30 and more people going down steps in 17:30-18:30.

4.2 Pathways of Dapuqiao Station square

In the same way, we took the videos of Dapuqiao Station square for two periods: 12:00-13:00; 17:00-18:00. Then we chose 5 minutes rush time video from every period and drew the pathways. In order to describe the situation of pedestrians clearly, we showed figures of pathways for 60 seconds. In Figure 7 and Figure 8, red lines

are pathways of going to entrance; blue lines are pathways of going to exit; green lines are pathways of passing. We find that there are more pedestrians to enter the gate in 17:00-18:00.

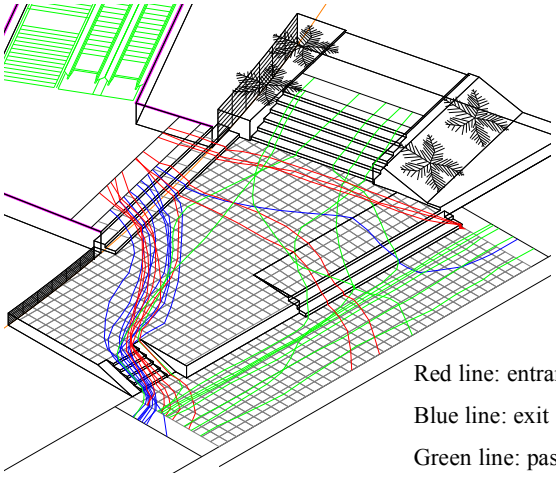

Figure 7 Pedestrians' Pathways on Dapuqiao Station Suare (60s in spare time 12:00-13:00)

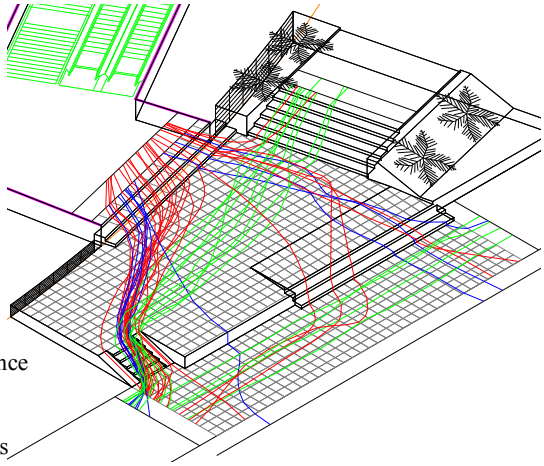

Figure 8 Pedestrians' Pathways on Dapuqiao Station Square (60s in rush time 17:00-18:00)

4.3 Comparison

Pathways on the square of Dapuqiao Station are very concentrated and crowded. Although the square is huge, a large number of pedestrians choose the most narrow steps, because it is the nearest path. These results suggest that shortcut behavior on the square of Dapuqiao Station is more obvious than JR Nishi-Chiba Station.

5.0 Statistics of speed and density

5.1 Data

We got the time for one pedestrian through flat and steps by the video. The number of samples from this 5 minutes is 100 on the flat and 100 on the steps for every period. The speed and density of samples will be counted one by one.

5.2 Definition

Speed is the speed that one person was walking on the step or on the flat at the midpoint of the pathway.

Density is the density that this person was walking at the midpoint of pathway.

5.3 Statistics

From the statistics of data, we could describe the characteristics of speed and density during different periods on the two squares.

5.4 Period comparison

5.4.1 Speed

In this statistics, speed is a key point, because it is an indicator that we can evaluate walking is free or not. The speed of pedestrian is slow at the period of spare time; and it is fast at the period of rush time on these two squares. The effect of time is significant.(Table 1)(Table 2) In the same time, the variation of speed on flat and on steps is uniform.

All in all, under the mid-low density condition, the speed of pedestrian is fast and walking is comfortable, but we can not say that walking is free completely. We must consider other condition.

Table 1 Period Comparison Speed Statistics on JR Nishi-Chiba Station Square(m/s)

Time	Position	N	Mean	Std. Deviation
12:30-13:30	Flat	100	1.4099	0.22514
	Steps	100	0.8159	0.16402
17:30-18:30	Flat	100	1.5737	0.25870
	Steps	100	0.9790	0.24276

Table 2 Period Comparison Speed Statistics on Dapuqiao Station Square(m/s)

Time	Position	N	Mean	Std. Deviation
12:00-13:00	Flat	100	1.3335	0.2299
	Steps	100	0.7199	0.1539
17:00-18:00	Flat	100	1.4880	0.2044
	Steps	100	0.8865	0.2009

As shown in Table 1 and Table 2, pedestrian's speed on the square of Dapuqiao Station is slower than JR Nishi-Chiba Station during these two periods of time .

5.4.2 Density

On JR Nishi-Chiba station square, the density of pedestrian is low in 12:30-13:30,

the mean of density is 0.0888 person/m^2. And it is high in 17:30-18:30, the mean of density is 0.1517 person/m^2.(Table 3) On Dapuqiao Station square, the mean of density is 0.0896 person/m^2 in 12:00-13:00 and 0.1293 person/m^2 in 17:00-18:00.(Table 4) There are middle density condition at times and low density condition at times on these two squares.

Table 3 Period Comparison Density Statistics on JR Nishi-Chiba Station Square(p/m^2)

Time	N	Mean	Std. Deviation
12:30-13:30	200	0.0888	0.0471
17:30-18:30	200	0.1517	0.0566

Table 4 Period Comparison Density Statistics on Dapuqiao Station Square(p/m^2)

Time	N	Mean	Std. Deviation
12:00-13:00	200	0.0896	0.0324
17:00-18:00	200	0.1293	0.0286

5.5 Position comparison

There are two parts on this square: flat and steps. As shown in Table 5 and Table 6, the speed of pedestrian on the flat is fast in 2 periods of time, it is 1.4918 m/s on JR Nishi-Chiba station square and 1.4108 m/s on Dapuqiao Station square. The Speed of pedestrians on the steps is slow in 2 periods of time, it is 0.8974 m/s on JR Nishi-Chiba station square and 0.8032 m/s on Dapuqiao Station square. The variation of pedestrian speed on the flat is larger than on the steps on these two squares.

Table 5 All Periods Speed Statisticson on JR Nishi-Chiba Station Square(m/s)

Position	N	Mean	Std. Deviation
Flat	200	1.4918	0.25546
Steps	200	0.8974	0.22223

Table 6 All Periods Speed Statisticson on Dapuqiao Station Square(m/s)

Position	N	Mean	Std. Deviation
Flat	200	1.4108	0.2304
Steps	200	0.8032	0.1971

5.6 Up & down comparison

Taking the speed of going up steps and going down steps into consideration, we do some statistics as Table 7 and Table 8. The results suggest that speed of going up

steps is slower than going down steps on these two squares.

Table 7 Steps(up & down) Speed Statistics on JR Nishi-Chiba Station Square(m/s)

Steps	N	Mean	Std. Deviation
Up	77	0.8106	0.18761
Down	123	0.9518	0.22558

Table 8 Steps(up & down) Speed Statistics on Dapuqiao Station Square(m/s)

Steps	N	Mean	Std. Deviation
Up	135	0.7735	0.20218
Down	65	0.8649	0.17163

6.0 Analysis

After the statistic of speed and density, we calculated separately the correlation between pedestrian's speed and density on the steps and on the flat in the spare time and in the rush time.

6.1 Flat and Steps speed-density linear fit comparison on JR Nishi-Chiba station square

Figure 9 and Figure 10 are the speed-density scatter diagrams of flat and steps on JR Nishi-Chiba station square. According to scatter of two figures, the scatter distribution of Figure 9 is more uniform than Figure 10. And the characteristic of fit linear of flat is more obvious than fit linear of steps. In other words, the correlation between speed and density on flat is more obvious than on steps.

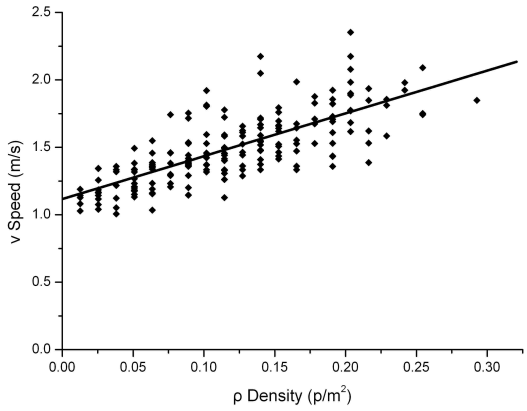

Figure 9 Flat Speed-density Linear Fit (2 periods of time) n=200

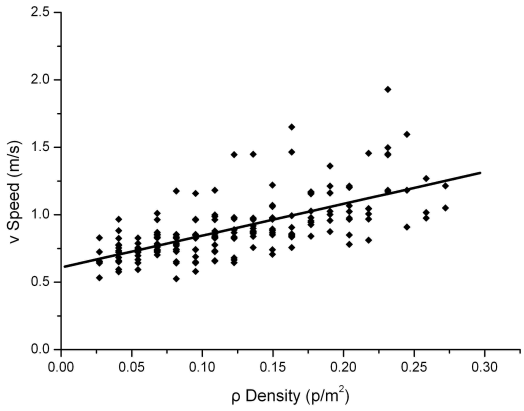

Figure 10 Steps Speed-density Linear Fit (2 periods of time) n=200

On the other hand, The fit linear of flat is steeper than steps, so variation of speed on flat is faster than on steps.(Figure 9, Figure 10)

6.2 Flat and Steps speed-density linear fit comparison on Dapuqiao Station square

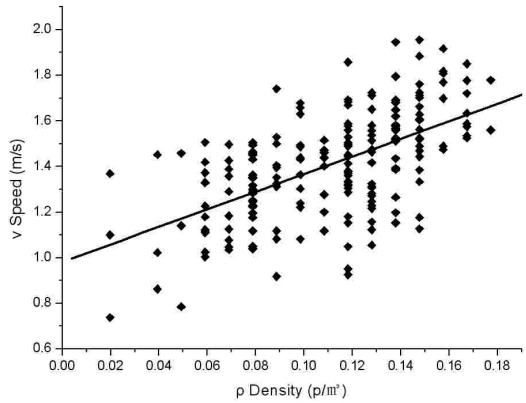

Figure 11 Flat Speed-density Linear Fit (2 periods of time) n=200

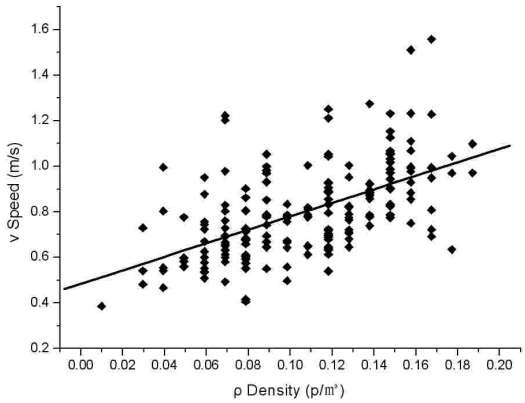

Figure 12 Steps Speed-density Linear Fit (2 periods of time) n=200

Although, the central tendency of the fit linear on Dapuqiao Station square is not stronger than on JR Nishi-Chiba station square, the characteristic of fit linear is obvious. In other words, it is necessary to discuss correlation between speed and density of these two squares. The fit linear of flat is steeper than steps, so variation of speed on flat is faster than on steps.(Figure 11, Figure 12)

6.3 Correlation between speed and density on JR Nishi-Chiba station square

Table 9 shows the correlation between speed and density. On the flat, the correlation is 0.755; on the steps, the correlation is 0.649. Wherever on the flat or on the steps, the correlation is significant at the 0.01 level(2-tailed). It shows that the speed and the density appear weak correlation in relation to the mid-high pedestrian density, but it is positive correlation.(Density is the most important effect on speed under the high density condition, but it is one of effects on speed under the mid-low density.)

The point of positive correlation is very important, because it is different from under the mid-high pedestrian density. Despite that this research have some differences of research condition and method from the previous researches, it is an interesting result nevertheless.(Table 9)

Table 9 Correlation between Speed and Density on JR Nishi-Chiba Station Square

Position	N	Correlation (speed & density)	Sig. (2-tailed)
Flat	200	0.755(**)	0.000
Steps	200	0.649(**)	0.000

** Correlation is significant at the 0.01 level(2-tailed).

6.4 Correlation between speed and density on Dapuqiao Station square

As shown in Table 10, the correlation between speed and density on the flat is 0.581, and the correlation between speed and density on the steps is 0.573 on Dapuqiao Station square.

The correlationn between speed and density on Dapuqiao Station square is weaker than on JR Nishi-Chiba station square. It is the result of pedestrians and environmental(the station square) interaction: Dapuqiao Station square is more complex than JR Nishi-Chiba station square; there are some different characteristics of pedestrians in different areas.

Table 10 Correlation between Speed and Density on Dapuqiao Station Square

Position	N	Correlation (speed & density)	Sig. (2-tailed)
Flat	200	0.581(**)	0.000
Steps	200	0.573(**)	0.000

** Correlation is significant at the 0.01 level(2-tailed).

7.0 Conclusion

After the analysis, the characteristics of pedestrian behavior were as follows:

General characteristics on the two squares: the speed is slow and the density is low in the spare time; the speed is fast and the density is high in the rush time. The speed on the steps is slower than on the flat. Under the mid-low density walking space, the correlation between speed and density is weakly positive correlation. It is different from the correlation under the high density walking space. In other words, a certain degree of density can make pedestrians speed up.

Different characteristics on the two squares: pedestrian's speed on the square of Dapuqiao Station is slower than JR Nishi-Chiba Station. Shortcut behavior on the square of Dapuqiao Station is more obvious than JR Nishi-Chiba Station. These results suggest that pedestrians in some parts of China adopt shortcut rather than fast walking for quickly reaching the destination, however pedestrians in some parts of

Japan more adopt fast walking. These results are useful to create walking spaces which will be more suitable and effective for person's behavior in dissimilar cultural contexts.

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