Centre for Transport Studies
University College London

## Working Paper

# Investigating Use of Space of Pedestrians

**Taku Fujiyama**

Accessibility Research Group
Centre for Transport Studies
University College London
Gower Street, London, WC1E 6BT
United Kingdom

Tel: +44 (0)20 7679 1561
Fax: +44 (0)20 7679 1567
E-mail: taku.fujiyama@ucl.ac.uk

www.arg.ucl.ac.uk

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## Abstract

Understanding use of space of pedestrian is important to plan/design street environments or large public transport facilities. The purpose of a series of our research is to investigate use of space of various pedestrians in a variety of environmental situations. The research is a part of PAMELA project designed to test existing and proposed pedestrian environments and street facilities (i.e. a bus stop) under controlled conditions. This paper is aimed at setting out the background of the research, and presenting a basic frame work for subsequent research. Strength of our approach is the microscopic heterogeneous approach, where each walking person is regarded different from others. Relations among characteristics of pedestrians, characteristics of facilities/ environments, and resulting actions of pedestrians are carefully examined. Conclusion suggests directions of further research.

## Key Words

Pedestrians, special needs, use of space, microscopic, heterogeneous, accessibility, pedestrian simulation

## Definition of words

| | |
|---|---|
| Walking characteristics: | Characteristics of a person's walking, such as his/her walking speed, direction, and collision avoidance manoeuvre against another person or an object |
| Resulting action: | Action taken by a person as a result of comparison between a person's capabilities (i.e. climbable height) and capabilities required by environments (i.e. height of a vertical difference (a stair)) |

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# Contents

# 1. Introduction

Demands of pedestrian facilities in a town/city are increasing. Understanding movements of pedestrians is therefore essential to plan and design facilities.

Hitherto, many studies on the pedestrian movement have regarded pedestrians as a flow, and seldom focused on each pedestrian or differences of walking characteristics among pedestrians. In order to materialise comfort of pedestrians and accessible/user friendly designs, more research is required that doesn't ignore differences of pedestrians.

Moreover, existing studies have scarcely considered how design details of walking facilities or environments affect pedestrians. For instance, there has been little research on how lighting affects movements of pedestrians. Because civil engineers/architects can't change characteristics of pedestrians but can change characteristics of facilities, more research on these issues is necessary.

As a part of our ongoing research project that examines interactions between pedestrians and environments, this paper looks at how characteristics of pedestrians and/or characteristics of environments affect walking characteristics of pedestrians. Our interest in this paper is particularly in use of space of pedestrians in a variety of environment. (I.e. on a dark street, on a slipper surface…etc) We use a laboratory, which can represent various environments under scientifically controlled conditions.

This paper is aimed at setting out the background of the series of our studies, and presenting a basic frame work for subsequent studies. Following studies will pick up and examine each topic based on the framework represented in this paper.

In this paper, Section 2 describes the context and target of this research. We see why spatial usage is focused. Section 3 portraits the approach of this research to this use of space of pedestrians, followed by Section 4 where the research methodology is illustrated.

The eventual goal of our research is not only to obtain knowledge for planning/design of pedestrian facilities but also to provide empirical data for our heterogeneous pedestrian simulation, which can represent a variety of pedestrians in various facilities/environments. We are planning to use our simulation in planning/design of streets or large transport facilities, such as railway stations.

# 2. Context/ Target of this research

## 2-1. Comfortable walking space

Recently, “walking” enjoys more and more attention from not only transport planners/ designers but also the public, because it is matching various requests of the recent society. Walking is an environment-friendly transport mode because it doesn’t produce $CO_2$, $SO_x$ as do cars. Walking is good for people to maintain/improve their health. Walking around a town/city offers a pleasant time for citizens. Not only benefits for individuals, walking supports the fabric of society. For example, walking is essential in terms of the access to shops or public services. Many towns/cities are now trying to create/improve environments for walking.

Despite of its many benefits, walking has seldom been focused for a long time as an object of transport infrastructure introduction/improvement. A reason could be that walking is a so basic movement and people can walk anyway in most environments. For instance, in order to pass a car, an about 3.0m width space is necessary and curves of roads should be not so sharp. On the other hand, just a 0.8m width space is physically enough for pedestrians to pass it and pedestrians can turn with a right angle if they are fit and agile.

An important issue to promote walking is to create comfortable space for walking. Conditions for comfortable walking are very different from minimum requirements for walking. Imagine a 1.5m width footpath beside a busy road. Although physically people can walk on it, nobody wants to do so.

Standards for walking facilities/environments have tended to see only such minimum requirements, partially because it would be difficult to establish conditions for comfortable walking. We don’t know much about criteria for comfortable walking. Nevertheless, in order to promote walking and to create comfortable walking environments, we need more understanding of such criteria/conditions.

## 2-2. Use of space

The aim of a series of our research is to further understand walking in order to create comfortable walking environments. The first phase of the research is concentrating on spatial usage of pedestrians. There are several reasons to choose spatial usage. First, space is one of the basic elements that planners/designers can change. Secondly, minimum requirements of space for walking are very different from requirements/conditions of space for comfortable walking. Thirdly, use of space is a topic that has not been carefully investigated because of technical reasons (i.e. detailed tracking). Recently developed technologies (i.e. laser scanners) make explicit analysis possible.

We regard use of space of a walking person as an indicator that shows his/her reaction to the given walking environment. With this indicator, we can know how a walking person perceives/reacts to the given walking environment. This knowledge is useful for creation of facilities/environments.

Also, use of space reflects the manoeuvre or agility of each pedestrian. By considering the agility of pedestrians, transport facilities planners/designers may realise comfortable walking environments in terms of walking manoeuvre.

Moreover, as personal space research has suggested (see section “Existing research”), a person has a portable territory around him/her. If it is invaded, she/he feels uncomfortable. We regard use of space as an indicator of how much space a walking person in a given condition requires for comfort or/and for safety being achieved by establishment of his/her portable territory. Of course, actual use of space is not always the same as the desired usage (i.e. Imagine a pedestrian in a very crowded space. Although he/she wants to keep some distance to an adjacent pedestrian, it is not always possible.) However, we know a person tries to achieve the maximum comfort in a given condition. Looking at use of space of pedestrians in a variety of environments that are scientifically controlled may help us further understand walking.

In order to conduct detailed investigation, we will set up a laboratory where we can scientifically control walking environments. Our ultimate goal is to offer useful knowledge to transport facilities planners/designers or architects. Because designers/planners can only change such environmental factors, detailed investigation of environmental factors that possibly affect walking is of significant use (Cepolina and Tyler (2004)).

Another purpose of this research is to provide detailed data for pedestrian simulations, which is gaining popularity in transport facilities planning/ design. Most of the pedestrian simulations apply fluid theories to movements of pedestrians. However, little research has been conducted on detailed movements of pedestrians and whether they match fluid theories. Detailed tracking data of pedestrians are of use for further development of pedestrian simulations.

# 3. Existing studies

This section presents existing walking studies related to our research. First, we look at pedestrian flow studies. Then, we will see studies that investigated use of space by people or how characteristics of people affect their use of space, followed by studies that looked at environmental effects on use of space of pedestrians.

## 3-1. Pedestrian flow studies

Hankin and Wright (1958), Older (1968) and Navin and Wheeler (1969) were recognised as pioneers of the pedestrian studies. Fruin (1971) deserves a mention for his achievement. He introduced a notion of "Level of Service", which is used to illustrate the comfort in driving cars on highways, into pedestrian studies. The main interest of these early studies was the capacity of the pedestrian path. They basically examined the relation between the density of pedestrians and the walking speed.

At a later stage, research focus transferred to the pedestrian-flow in various spaces. Daly *et al* (1991) observed the pedestrian flow in underground stations. Similarly did Lam *et al* (2000) conducted an observation in railway stations in Hong Kong. Kwon *et al* (1998) expanded "level of service" concept to mixed traffic roads. They studied a narrow residential road, where cars, bicycles and pedestrians share the same space. Lam *et al* (2003) considered a bi-directional flow in a (x, y) space.

## 3-2. Spatial usage of pedestrian (analysis of pedestrian factors that affect use of space)

### a) Personal space studies

In this part, we look at so-called "personal space" or "proxemics" studies. These studies have been interested in the territory of a person or persons, and researchers have regarded an interpersonal distance as an index of their interpersonal relation. Because personal space research has been performed mainly by sociologists, anthropologists and psychologists, the research interest has been rather in social contexts (i.e. affection of social positions), and the observed or experimented situations have been mostly static. We haven't known how the size of such a comfortable space for a person changes when the person is walking. Although it may not be always possible to apply knowledge of existing personal space research for pedestrians, contributions of these studies are large.

Hall (1966)'s work should be marked for establishment of the concept of personal space, and so far has been referred in many studies in many disciplines. Central to his concept is the territory of man. According to Hall, interpersonal distances can be divided into four categories according to the attitude of a person toward another person or according to the relation between two persons. The four categories are

a) Intimate zone (0.0-0.5m) for persons with a very special relationship. (i.e. a boy friend and a girl friend)

b) Personal zone (0.5-1.2m) for a person to a known person (i.e. a friend)

c) Social consultative zone (1.2-4.0m) for a person to a unknown but permitted person to communicate (i.e. a counterpart of business)

d) Public distance (4.0m-10.0m) for a person to unknown person

It should be noted that, as Hall himself pointed out, the distances may be fluctuate according to various conditions. Several studies found that the size of personal space is different between men and women or among age groups. Also, people show different distances to disabled people from those to ordinary people (i.e. Worthington (1974) or Kilbury (1996)).

Hyduk (1978) went father from Hall's research. He defined personal space as "the area individual humans actively maintain around themselves into which others cannot intrude without arousing discomfort". Indeed, Hyduk (1981) found a linear relation between intrusion of the personal space and discomfort, followed by several studies including Sawada (2003) that found a significant change of the heart rate of subjects while they were approached by a stranger.

Sobel and Lillith (1975) examined personal space in non-static situations. His method was that an male or female experimenter was approaching to a subject on a high street, and observers recorded the distance where the subject began deflecting collision. In his experiment, the average distance to male experimenters from subjects to begin deflection was 94.2cm, whereas that to female experimenters was 142.0cm. Also, there were no differences in the amount of distance given by male subjects (117.9cm) and female subjects (118.1cm). This result was different from other studies that investigated the sex difference in personal space (i.e. Sibuya (1985)), which found that women showed less personal space than men. Another important finding of Sobel and Lillith was that in their experiment, where an experimenter walked straight to a subject and didn't give way to the subject, 42% of trials ended up with a physical contact. They suggested the presence of a strong norm of bilateral accommodation in street behaviour.

One limitation of the work of Sobel and Lillith could be that their study was an observational study, where all conditions were not controlled. For example, the density, or presence of another person around a subject might lead to a different result.

Caplan and Goldman (1981) found that people invaded the space of short confederates more frequently than tall confederates. Harnett *et al* (1974) found that people approached a short object more closely than a tall object.

Webb and Weber(2003) investigated the influence of characteristics of elderly participants on their personal space. The investigated characteristics were age, sex, vision, hearing and mobility. They found that age, gender and mobility played an important role to establish personal space. An interesting finding was that perception (by approached elderly subjects) of physical strength and aggression of approaching person didn't have a strong influence on interpersonal distances.

### b) Other research

It has been well known that women tend to walk more slowly than men. Also, Leg Extensor power affects walking speed. Fujiyama and Tyler (2004) presented a literature review of research on the walking speed.

There has been some observational research on collision avoidance behaviour. Willis (1979) reported that 1) women didn't tend to move for men, 2) persons or groups moved for larger groups and 3) younger groups tended to move for older groups. He suggested that manoeuvrability might be an important factor to determine which one avoids. An interesting finding of Dabbs (1975) was that a pedestrian more often changes the direction for an attractive female than for an unattractive female. Some other research suggested psychological effects on deciding the person who gives way. For example, affection of the human power relationship was suggested by Henley (1977), or resoluteness by Goffman (1971).

## 3-3. Environmental factors that affect use of space of pedestrians

At first, Hill (1984) is worth being mentioned as a good review of pedestrian research. His research is of use for detailed investigation of past research.

It has been hypothesised and indeed investigated for a long time that vision plays an important role in sensing environments. One implication can be the effect of lighting.

Adams and Zuckerman (1991) investigated the effect of lighting on personal space requirement. He used stop-distance technique, where stationary subjects were approached by an experimenter and asked to say “stop” when the subject felt discomfort because the experimenter reached too closed to the subject. The distance between the subject and the experimenter was recorded. Adams found that the subjects tested under a dim condition (1.5 (lx)) preferred to be at significantly greater distances from the experimenter than those tested under a bright condition (600 (lx)). This corresponded with Hall (1966)’s suggestion that personal space sizes might become larger in a noisy or/and dark situation.

Van Bommel and Caminada (1982) was an attempt to establish lighting parameters of street lighting in residential areas based on Hall (1966)’s concept. He argued that identification of the face of another pedestrian is the most important for pedestrians in the interest of security, and that, referring to the minimum limit of “public zone” of Hall (4.0m), the street lighting should be bright enough to ensure that a pedestrian can recognise the face of another unknown pedestrian before this unknown pedestrian reaches less than 4.0m to him/her. (The darker a street, the shorter the facial recognition distance becomes.) This work should be marked as an attempt to apply the personal space knowledge for a practical field, and to qualitatively examine the minimum lighting level. In fact, the minimum standard for residential roads of British Standard (5.0(lx) for S1 class road) was decided based on Bommel’s work. However, it should be noted that, as Hall himself suggested and Adams (1991) proved, the zones of personal space become bigger in a dark condition, and therefore it should be re-examined that whether 4.0m is enough to keep the distance of “public zone” under a dark condition.

Raynham (2003) further developed this van Bommel’s idea, and examined the difference of lamp types in terms of endurance of facial recognition. His finding was that the white light is significantly better than the yellow light which is commonly used for street lighting.

While researchers have focused on visual aspects of environments, Rapoport (1977) underscores the importance of other environmental factors, such as the sound, air movement, temperature and smell, and of facilities factors, such as tactile sensations.

There have been some studies on effects of the sound on pedestrian movements. These research has been regarded the sound as “noise”, which is rather an unpleasant environmental stimulus, and has investigated behaviour of pedestrians exposed to the stimulus. The idea for these noise studies was originated from “input overload” hypothesis by Milgram (1970). The hypothesis is that a person subjected to a level of environmental inputs that is in excess of his/her capacity to effectively deal with them will adopt tactics to reduce the pressure of these inputs to a more tolerable level. An input is considered to be any environmental stimulus, such as the sound, sight, which is capable of being responded to or noticed. Boles (1978) examined the relation between environmental stimuli and cooperation/walking speeds of pedestrians, and confirmed an effect of environmental stimulation on the walking speed. His research was followed by Korte and Grant (1980).

Stilitz (1970) reported negative attitudes of pedestrians to congestion. Some respondents in his research described the situation as “irritating” because “other people get in the way”, “you have to avoid people”, or “you have to pay attention.”

Characteristics of facilities also affect walking characteristics of pedestrians. Affection of stair-gradient on the walking speed was investigated by Fujiyama and Tyler (2004).

Moreover, some personal space research that examined affection of facilities factors should also be mentioned here. White (1975) found that when the room size decreases, people prefer more interpersonal space. Savinar (1975) and Cochran and Urbanczya (1982) suggested that when the ceiling height decreases, people prefer more interpersonal space. Cochran *et al* (1984) found interpersonal distances in indoor is larger than in outdoor.

# 4. Proposed approach

## 4-1. Understanding “Walking”

Walking is an essential movement of human beings. Not only transport researchers or architects but also various disciplines, including medicine, psychology and sociology, look at walking. In spite of much research so far, there seem to be much room left for further research.

As a result of our intensive literature review on walking, we found that walking is actually a complex movement that consists of various basic movements, such as seeing a way forward with eyes, analysing information from eyes in brain, taking a balance and moving two legs with a good combination. These basic movements may fit into three categories, namely sensing “sensing”, “judging” and “output”, but details of this categorisation will appear in another paper. An important point is that such various basic movements are simultaneously and collaboratively conduced. For example, while moving legs, pedestrian simultaneously see a way forward. Visual information on an obstacle ahead influences leg movements.

Also, pedestrians can do other activities while walking. For example, it is common that some young people eat a hamburger while walking, or on a street people are talking to each other while walking. We can notice that the more attentions people pay to talking, at the less speed they are walking. Moreover, it is a usual scene in comedy movies that a walking person, who is simultaneously thinking a (philosophical) question, collides with an obstacle in front because he/she doesn't notice it.

It should be noted that environments require pedestrians to simultaneously conduct different tasks as well. A typical example is boarding a bus. Pedestrians (passengers) are required to climb a vertical difference between the pavement and the vehicle, to grasp a rail where necessary, to manage shopping bags/belongings on hands, to see where they pay a fare, to pick up their wallet, to pay the fare, to rotate their body and to proceed to inside the vehicle.

Since walking is composed by many basic elements and affected by various pedestrians/ environmental factors, an observational study on streets may have limitation because it is impossible on a street to control such many factors. A laboratory type approach where conditions are scientifically controlled is desirable.

## 4-2. Microscopic approach

Hitherto, many observational studies on pedestrian movement have been conducted especially in transport field. Most of them have considered pedestrians as a flow, and their intention has been to analyse pedestrians by flow indices, such as the velocity, density and path-width. We call them "macroscopic approach". This approach is suitable for planning/design mass pedestrian facilities, such as a railway platform for commuting people.

However, this macroscopic approach is not appropriate to obtain basic knowledge for creation of comfortable walking environments, because this approach ignores basic issues for the creation, such as how a person perceive environments, or how much space is actually desired by a pedestrian. Concentration on each person, who is affected by or reacts to a given environment, may provide more insights into interactions between pedestrians and environments.

## 4-3. Heterogeneous approach

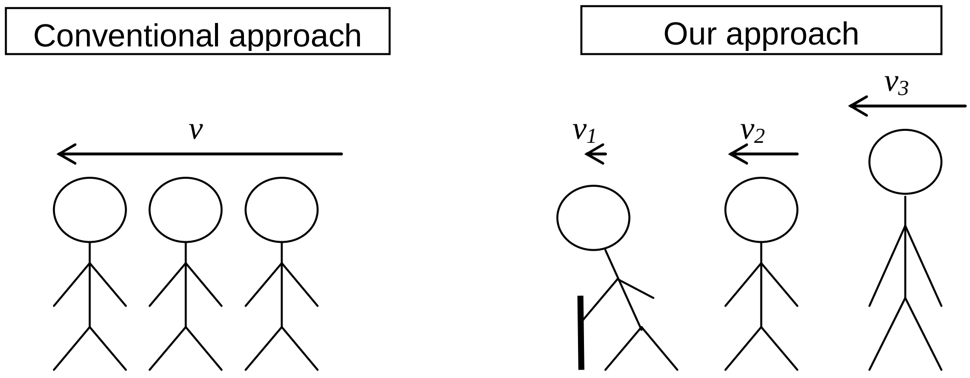
Much pedestrian research has been based on the assumption that characteristics of pedestrians are the same among pedestrians (i.e. Each pedestrian walks at the same speed as others). We call this approach "homogeneous approach". This approach has often been employed where transport facilities were designed to meet a substantial amount of demand (and where accessibility or comfort of users was ignored).

In reality, walking characteristics are different amongst pedestrians. For instance, elderly pedestrians walk more slowly than young robust pedestrians. Transport facilities or buildings may require more time for evacuation if there are many elderly users. If a path inside facilities is narrow, there may be a queue or speed down of crowds lead by a slowly walking pedestrian. Another example is use of space. Those who have shopping bags or a suitcase for a foreign travel occupy more space than others. Wheelchair users need more space to turn at a corner than ordinary pedestrians.

There are two reasons why we are interested in differences among pedestrians. First, the aim of this research is to offer knowledge and empirical data for planners/designers of transport facilities. Investigation of characteristics that affect spatial usage, which can be an indicator of a person who reacts to a given environment, may be of great use. By linking obtained knowledge/ data, which explore differences of pedestrians, to national demographic statistics, it is possible to examine characteristics of facilities/environment with a demographically quantitative approach and rates of changes in social participations (Tyler (1999)). Discussion of drawing a threshold, which distinguishes covered people from uncovered people, may be of use for investigation of limitation of the design.

Secondly, in the interest of the social inclusion, transport facilities must be accessible for all people including elderly or disabled people. Looking at differences between vulnerable people and robust people makes it possible to ensure integration of needs of vulnerable people. Also, consideration of such vulnerable people consequently leads easiness or comfort of use for other ordinary users (Fujiyama (2003)).

We call our approach "heterogeneous approach." In our approach, each pedestrian is focused. We don't regard pedestrians as a flow, which consists of the same constituents. Fig.1 is schematic representation of our approach in comparison with the conventional approach.




To look at pedestrians as a flow (assuming the characteristics of all pedestrians are the same) [homogeneous approach]

To look at each pedestrian at the individual level.
(assuming each pedestrian has unique characteristics)
[heterogeneous approach]

Fig.1: Comparison of our approach with the conventional approach

### 4-4. Resulting action

Each pedestrian shows his/her unique walking characteristics under a certain walking environment because his/her capabilities are unique. For example, an elderly person walks more slowly when ascending stairs than young people. Fujiyama and Tyler (2004) found that for elderly people, who have relatively less leg extensor power, the stronger leg extensor power an elderly person has, the faster he/she ascends stairs.

Also, the same pedestrian shows different walking characteristics according to the different environments. Fujiyama and Tyler (2004) found that the steeper the stairs, the more slowly a pedestrian walks on them.

We assume that each pedestrian has a set of (provided) capabilities (i.e. climbable height), and environment has a set of (required) capabilities (i.e. height of a vertical difference (a stair)). The action of a pedestrian in a certain environment (i.e. walking speed) is a result of interactions between the pedestrian’s (provided) capabilities and the environment’s (required) capabilities (Cepolina and Tyler (2004), Fujiyama (2004)). The strength of this approach is to consider both persons’ and environmental factors in the same comparison frame.

We regard use of space of a person as an indicator of his/her reaction to a given environment (or a result of comparison between a person’s (provided) capabilities and an environment’s (required) capability. In this paper, among various use of space actions, we are interested in following three actions.

A) Absolute stop/ proceed

B) Walking speed

C) Collision avoidance manoeuvre

Action A means a situation where a pedestrian can’t continue walking and stops. Imagine a person walking in a house in the night and suddenly the light is turned off. The person can’t continue walking because he/she temporarily loses his/her sight. Action B means a situation where a pedestrian needs to change his walking speed. For example, if from a certain point a slope gradient becomes very steep, the walking speed of a pedestrian on the slope may become slow. Action C means a situation where a pedestrian changes collision avoidance manoeuvre. For example, suppose a pedestrian avoids an electricity poll in front at nighttime. If it is very dark, the collision avoidance manoeuvre he/she takes may be different from the one in a bright condition. Fig. 2 is a schematic representation of this notion.

Note that we don’t consider origin/destination issues in our study and therefore we don’t take account of situations where a pedestrian changes his/her direction because of his/her intention to get the destination. However, we do look at the microscopic route choices (i.e. do I pass to the right or left of an oncoming pedestrian?)

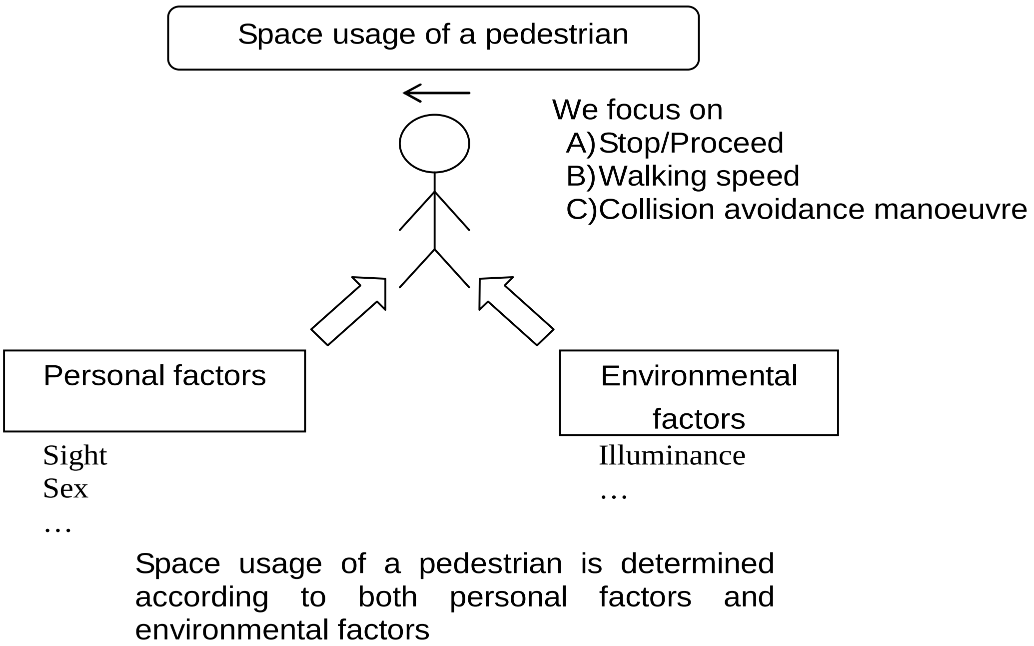



Fig.2: Structure of factors affecting use of space of a pedestrian

Among these resulting actions, this paper concentrates on Action C: Collision avoidance manoeuvre. (Action A and Action B will be investigated in other papers.) This is because collision avoidance is directly related to use of space of pedestrians. Also, knowledge/ empirical data on collision avoidance are useful for planning/design of walking spaces/ facilities, as well as for pedestrian simulation models.

# 5. Framework for experiments

## 5-1. Overview of PAMELA laboratory

In order to investigate use of space of pedestrians under a variety of facility/environment conditions, we perform a series of experiments. The experiments take place in PAMELA laboratory.

PAMELA laboratory is a mobile laboratory designed to simulate pedestrian environments and test them under controlled conditions. The facility consists of an elevated demountable paved platform that is about 7m square but able to be configured differently if required, thereby making it possible to create a variety of street conditions, such as vertical differences or a slope. The facility also has lighting and sounding systems, which are controlled by a computer. The equipped laser tracking system enables detailed analysis of pedestrian tracks.

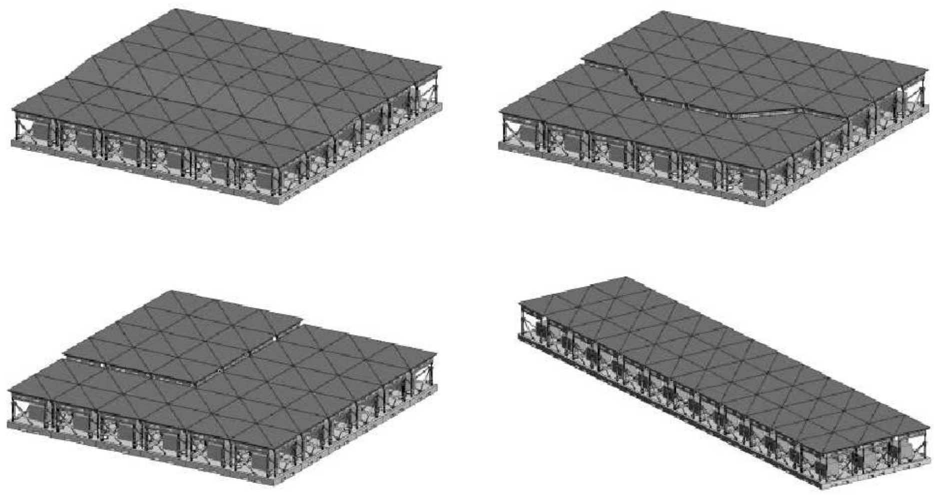


Fig. 3: Variation of PAMELA platform

## 5-2. Factors to be investigated

As stated before, we see three types of resulting actions, which are consequences of comparison between characteristics of pedestrians and characteristics of facilities/

environments. A brain storming was performed to find possible characteristics of both pedestrians and facilities/ environments that affect these three resulting actions. The result of the brain storming can be seen in Fig. 4.

For collision avoidance manoeuvre, not only characteristics of facilities/environments but also characteristics of an approached object may result in different resulting action details. For example, imagine a pedestrian is approaching to a stationary object. Size or the characteristics of the approached object (i.e. a postbox or a tiny rubbish) may alter details of his/her collision avoidance to the object (i.e. the distance to the object when he/she starts deflection to avoid the object).

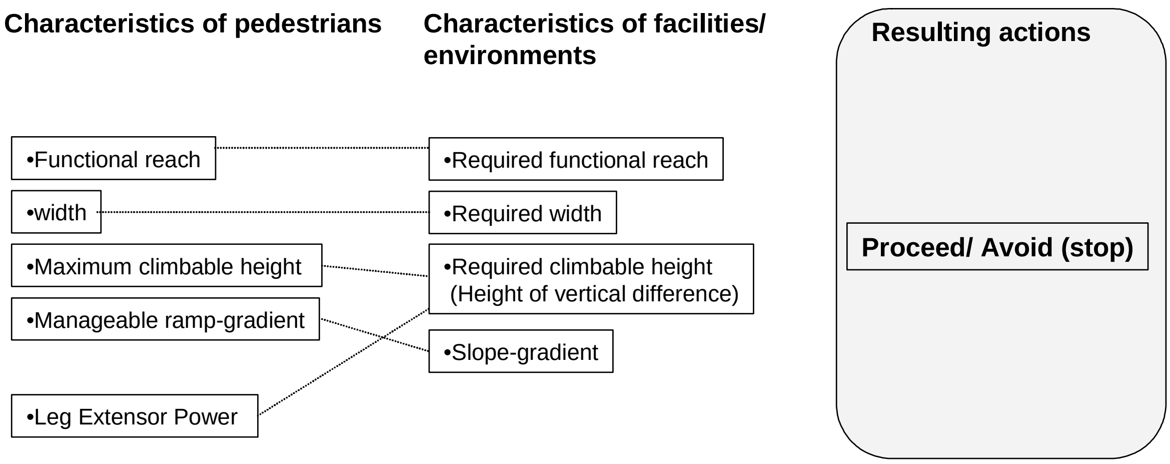



Fig. 4-1: Characteristics that may affect resulting action A: Stop/ proceed

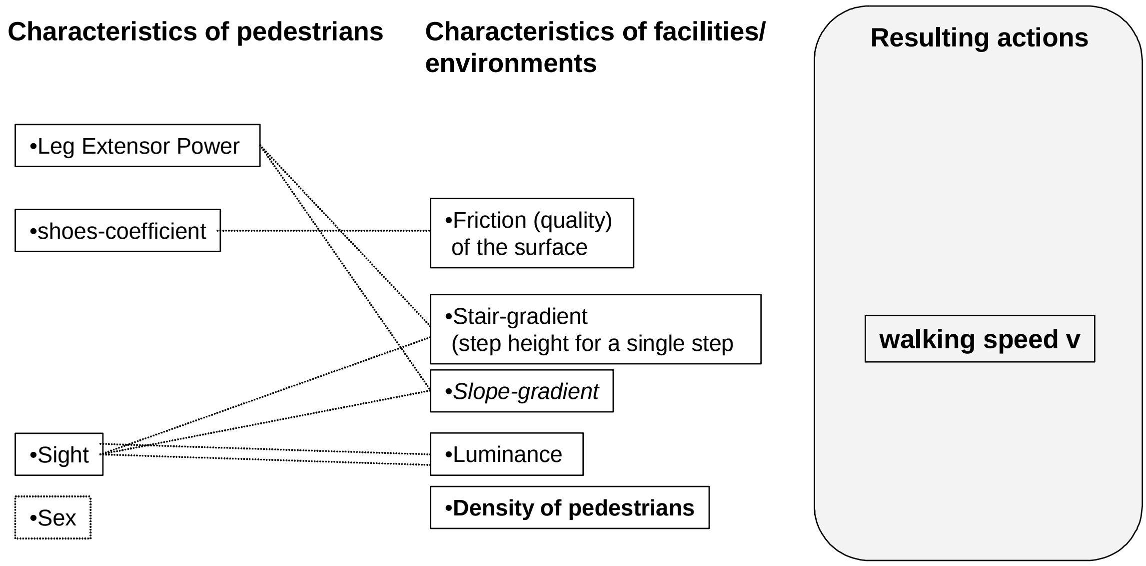
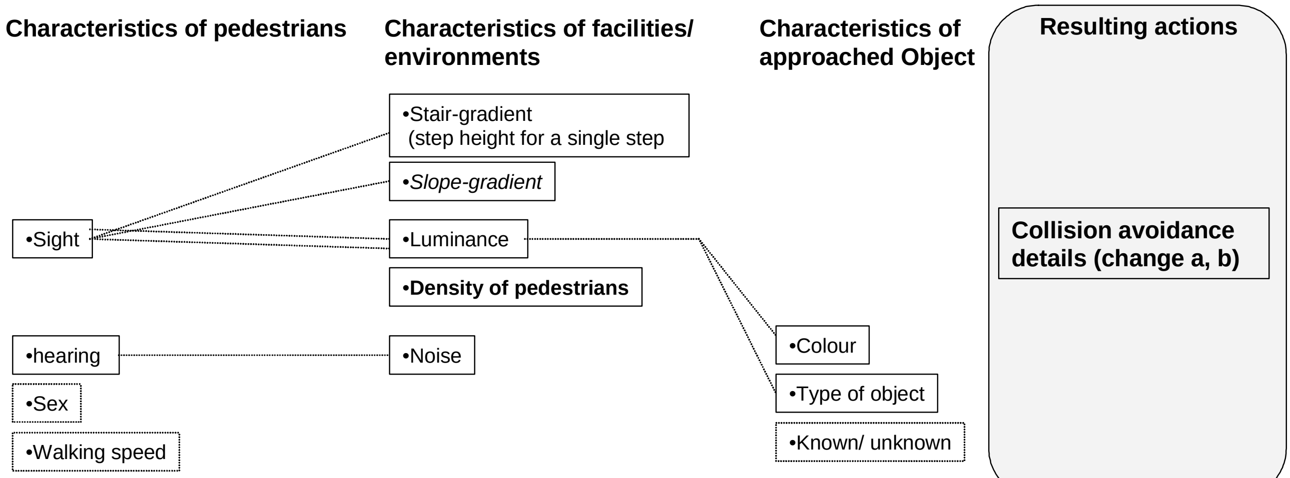



Fig. 4-2: Characteristics that may affect resulting action B: Walking speed




Type of object= {bin, chair, post, bicycle…}ß need to categorise

Collision avoidance distances (a, b): See fig 4-4

Fig. 4-3: Characteristics that may affect resulting action C: collision avoidance manoeuvre

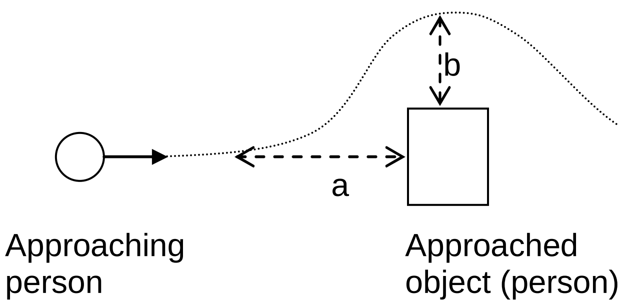



Fig. 4-4: Collision avoidance distances

In the first step of this series of research, this paper concentrates on Action C: Collision avoidance manoeuvre. As we have seen, collision avoidance of a pedestrian reflects his/her spatial requirements for the walking space. Requirements of the walking space are an indicator of various elements that should be taken into account in planning/design of walking facilities/environments.

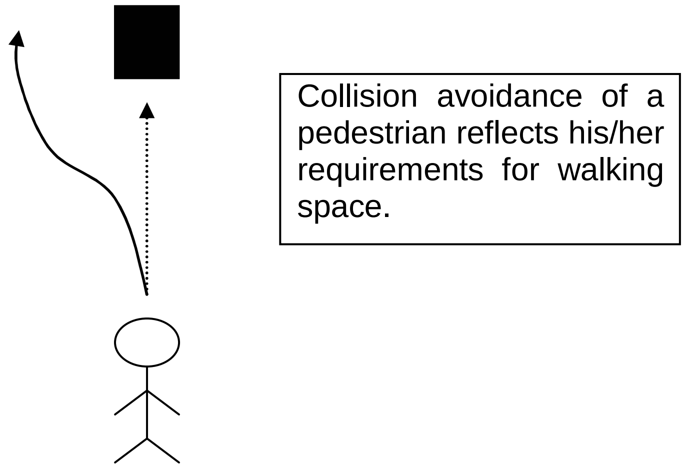



Fig. 5. Collision avoidance and requirements for walking space

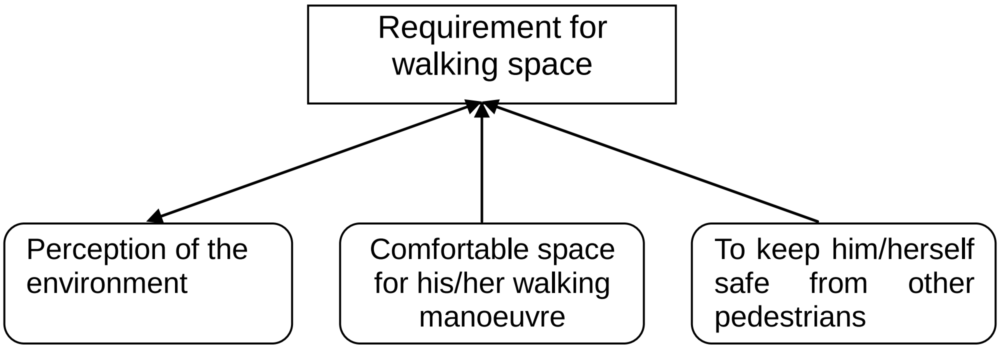



Fig. 6. Composition of requirements for walking space

## 6. Conclusion

The aim of the series of our research is to investigate use of space of pedestrians. As the introduction of the series, this paper focused especially on the background of the research and the basic framework of the research. Based on the framework, subsequent studies will look at each issue/element. One of the advantages of our approach is to look at each pedestrian. We regard walking characteristics of a pedestrian as the consequence of comparison between characteristics of the pedestrian and characteristics of a given environment/facility. We investigate relations among them.

From now on, we will perform a series of experiments according to the framework we proposed. The experiments will be conducted in a robust statistical manner. Also, we will link our results to other national statistics.

Obtained data and knowledge through this research can contribute to planning/design of pedestrian environments. Existing standards for transport facilities tend to be based on minimum requirements. Our research, which explores conditions for “comfortable” space, can offer insights of design criteria to create comfortable walking environments/ facilities.

Moreover, the obtained knowledge can be integrated into our pedestrian simulation, which can represent detailed movements of pedestrians. With this simulation, we can estimate how alterations of environments (i.e. introduction of a new lighting system on a street or in a subway) affect movements of pedestrians. This can be a useful tool for transport facilities planner/designers.

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