Centre for Transport Studies
University College London

Working Paper

Concept: Coping model to measure "Easiness" to manage a facility/service

- for evaluation of accessible designs -

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

May, 2004

Abstract

This paper presents a part of a research project that intends to develop an evaluation model for accessible designs in large public transport facilities.

Proposed evaluation model focuses on benefits of accessible designs to the public which consists of a variety of people including elderly and disabled people. In order to capture the benefits, the research has developed a new concept called "Coping model", which can describe situations where the more accessible the design of a facility or service, the more benefits a variety of people can receive.

A pedestrian simulation model has also been proposed as a tool to materialise the coping model. The simulation has been designed to represent interactions between people and facilities. A brief summary of the experiment performed to obtain empirical data for the simulation, whose results coincide with the coping model, was included as well.

Key Words

Accessibility, Public transport, Beneficiaries, Coping model, Pedestrian simulation

Definition of words

Capability: the ability to pursue a body function
Body function: the basic function of the human body, such as the ability to see.

Acknowledgement

This research project is a part of Taku Fujiyama's research in his PhD coursework under supervision of Professor Nick Tyler at the Centre for Transport Studies, University College London. His study is funded by Joint Japan/World Bank Scholarship Programme.
Discussions with Prof. Nick Tyler or Dr. Elvezia Cepolina at Dipartménto di Ingegneria Civile, Università di Pisa, Italy should be acknowledged as the basis of this paper.

Contents

1. Introduction

Today, accessibility for transport is an important issue to maintain the sustainability of our society. Laws and regulations order all new transport facilities be accessible, and transport companies are now trying to introduce accessibility into existing facilities. Experience so far teaches us that it is easy to realise accessibility when a facility is newly constructed, but it is strenuous and expensive to introduce accessibility into existing facilities, especially large public transport facilities such as underground stations. Under such a difficult situation, a detailed evaluation tool for accessible designs may help plan/design the introduction of accessibility. In fact, Government's 10-year Transport Plan, Transport 2010, claims the necessity of measures for evaluating accessibility in order to check that the investment for accessibility is delivering real improvements (DETR (2000)).

Accessible facilities are initially designed for disabled people, such as wheelchair users, or elderly people. However, it can be noticed that young healthy people also feel comfortable when they use accessible facilities, such as step-free stations. Those who are robust but carrying large heavy luggage may use lifts instead of stairs. Is it appropriate to categorise a person who is aged more than 70 but energetic, into "elderly"? Another example is a large gap between the platform and the railway vehicle. (i.e. a gap at Bank station on the Central Line of London Underground.) There may be some people who can't manage the gap although they are neither elderly nor disabled. (i.e. very young children or people with temporarily injured legs.) When thinking about these issues, a question arises: How can we define the beneficiaries of the introduction of accessibility? In the evaluation of benefits of accessibility, it would be reasonable to consider all people rather than only elderly or disabled people because all people are potentially beneficiaries.

This paper is an attempt to develop a new evaluation tool for accessibility. This research especially looks at the fact that the accessible design in public transport facilities brings benefits not only for elderly or disabled people but also all people with the diversity. Section 2 investigates literature pertaining to the evaluation of accessibility. Section 3 proposes a new model for the evaluation, and Section 4 gives details to the new model, followed by Section 5 where the practical application of the proposed model is discussed. In Section 6 there is a brief summary of an experiment designed to obtain empirical data for the proposed model.

2. Existing studies of the evaluation of accessibility

2-1. Introduction

The purpose of this section is to overview studies related to this research. This research is especially interested in how previous studies have defined beneficiaries of accessible facilities.

There have not been so many studies focusing on the evaluation of accessibility. Although the total amount of studies is not so large, existing studies may fit into following three categories.

a) People-oriented approach

b) Facility/service-oriented approach

c) Conjunction approach between people and facilities

In the people-oriented approach, studies have looked mainly at the mobility, including the transport usage, of elderly or disabled people. Facility or service-oriented approach has focused on facilities or services. In this approach, studies have investigated problems of conventional transport facilities or services, and also evaluated accessible facilities or services. Conjunction approach has scrutinised accessibility based on factors of both people and facilities/services.

In the following sub-sections, this paper looks at details of each category.

2-2. People-oriented approach

People-oriented approach has looked mainly at the mobility and characteristics of transport usage of elderly or disabled people. These studies have provided knowledge and empirical data that are essential for planning/design of accessible transport facilities or systems. Studies in this category may fit into these two sub-categories.

α) General activity approach

β) Psychological/Ecological approaches

α) General activity approach

General activity approach has studied activities of elderly or disabled people. Hitherto, most of the studies in this approach have been conducted by public sectors. An example of studies for the elderly was DTLR (2001). An example for disabled people was Martin *et al* (1989)

Note that there have been also some studies targeting the transport usage of elderly or disabled people in a specific mode transport, which will be examined in section 2-3. One feature of this approach is that studies have looked at whole daily lives of elderly or disabled people and considered the move or the transport usage as an element of their lives.

In this approach, an important issue is selection of indices to describe the mobility. Proper indices make it possible to quantitatively evaluate activities. Some studies investigated such indices (DfT(2003), SEU(2002)). However, activities of people have many dimensions, and therefore it is difficult to measure them. So far there has been no established index to describe activities of the elderly or the disabled.

Some studies on attitudes of elderly or disabled people to general transport systems may also fit into this sub-category. (i.e. MORI(2002)).

β) Psychological/Ecological approaches

Research in this sub-category has aimed to understand psychological or ecological systems for the movement/activity of elderly or disabled people. This understanding can be of help to consider a framework for the evaluation of accessibility. An example of psychological studies is Brown (2001), which employed psychological methods to assess the driving ability after a stroke. An example of ecological studies was Chibana (1998), which studied the fixation of wheelchair people around pedestrian crossings.

In order to realise accessible facilities (environments), it is necessary at first to understand the mobility of elderly or disabled people. However, a question to this approach can be that "How can we improve accessibility of public transport facilities?" As Cepolina and Tyler (2004) pointed out, the only element which transport planners/designers can build/modify is not elderly or disabled people themselves but transport facilities, and therefore we need to know how facilities affect accessibility of elderly or disabled people. This paper then looks at the facility/service-oriented approach.

2-3. Facility/service-oriented approach

In this facility/service-oriented approach, studies have directly assessed transport facilities or services. The studies have been performed mainly by looking at the compliance of a facility or service with standards/guidelines for accessibility, or by surveying opinions of users of a facility/service. Studies in this approach may fit into following four sub-categories (approaches).

α) Assessment of facilities/services by surveying opinions of elderly or disabled people

β) Assessment of facilities/services by physical indices

γ) Standard or guideline (i.e. door size, gradient of ramps) and compliance with them

δ) Mobility in/on accessible facilities

α) Assessment of facilities/services by surveying opinions of elderly or disabled people

Studies in this sub-category are the assessment of a facility/service by surveying opinions of elderly or disabled people. Questionnaire is a typical method of studies in this approach. There have been many studies in this sub-category because of the nature of this approach, where studies can be simple and straightforward comparing with other studies. An example of this category is Currie (2001), which presented Air Travel Accessibility Survey in Canada.

However, since evaluation in this approach is dependent on opinions of users, it is impossible to exclude some bias amongst the users. This also infers the difficulty in evaluating in a precisely quantitative manner.

β) Assessment of facilities/services by numerical indices

Studies in this sub-category are the assessment of a facility/service by numerical indices, which are not related to the survey of users' opinions or another form of user-opinion methods. For instance, Barham *et al* (1994) assessed bus routes by examining a distance from each residential home to the nearest bus stop. Wu and Hine (2003) evaluated a bus service of a city by measuring the access time from each house to a bus stop. Caiaffa and Tyler (2001) compared a new structural design for bus stops with an old design by examining distances (gaps) between bus vehicles and platforms.

This approach is employed mainly for comparison of several scenarios by one objective and numerical factor, such as the distance to a bus stop. Therefore, adequacy or explicitness of the index utilised to represent the problem is essential.

γ) Standard or guideline (i.e. door size, gradient of ramps) and compliance with them

Many regulations or guidance for facilities/services numerically regulate facilities' designs or services in order to guarantee a certain level of accessibility. These regulations or guidance can be a standard for evaluation. For example, DETR (1992) regulates the maximum gradient of a slope in public facilities or the minimum width of a door in the entrance of buildings. Table.1 shows other regulations pertaining to the public transport.

Table.1 Regulation for accessibility of the public transport

Object	Regulation
Railway	EU/DGT (1999)
Low floor bus	EU/DGT (1995)
Small buses	DPTAC (2001)
Pedestrian routes	IHT (1991), DETR(1998)

Extracted from DfT (2003)

δ) Mobility in/on the accessible facilities

Some studies have focused on the mobility of elderly or disabled people in/on a specific transport facility. Knowledge and empirical data gained through these studies are of use to plan/design accessible transport facilities. Mizukami (2002) observed the mobility of passengers in a rail station. Knoblauch *et al* (1996) examined the mobility of elderly pedestrians at pedestrian crossings. Other than Knoblauch, there have been are many studies on pedestrians on zebra crossings.

This paper has looked at studies categorised into the facility/service-oriented approach. As studies have directly examined a facility/service, it is easy to gain some results. However, in reality there is diversity among the users of a facility/service, and therefore needs for a facility/service also may vary. In the evaluation of accessibility, it may be legitimate to consider factors of both people and facilities/services. For example, suppose an introduction of a new accessible bus service into two areas: X and Y. Assume that an accessibility index of the bus service, such as the access distance or the access time to a bus stop from each house, shows the same value. If Area X has many elderly people whereas in Area Y young people are the majority, can it be still claimed that the benefit of the new bus service in terms of accessibility is the same in both X and Y because the index (the access distance/time) shows the same value?

In the next section, this paper will look at an approach that considers both users and facilities/services.

2-4. Conjunction approach between people and facilities

In this Conjunction approach between people and facilities, studies have taken account of both users and facilities/services. Because the approach presented in this paper may be categorised into this approach as well, this paper closely looks at existing studies in this category. There have been two groups of studies that fit into this category.

α) Iwarsson and Ståhl(1999) and Jensen *et al* (2002) (Swedish studies)

Iwarsson and Ståhl (1999) mentioned that "knowledge about the relation between functional limitations (of people) and environmental demands needs to be developed." Jensen *et al* (2002) described that "When assessing the accessibility in public transport traditionally, often the only dimension taken into account is the physical one (human factors)." However, "accessibility is the relation between functional capacity and environmental demand" (Jensen *et al* (2002)). For example, severity of a gap between a platform and a vehicle may be different between a healthy person and a person having a big problem with his/her leg. This series of Swedish studies have also emphasised the necessity of collaboration between the transport planning/design, which has been specialised in facilities/services, and other medical/human studies, which have focused on people's factors.

As a tool for this collaboration, Jensen *et al* (2002) proposed a model, derived from the Enabler concept[*], that can take account of both people's factors and environmental factors. Although they have yet to present a whole picture of their model, we can see their basic idea in Fig.1 that shows House enabler model developed initially for the evaluation of accessibility of a house.

The advantage of their model was that the model can reflect both environmental and personal factors. This model should not be ignored as it showed a new avenue for the evaluation of accessibility, which had considered only either environmental factors or personal factors.

[*] See URL section of bibliography for "Enabler"

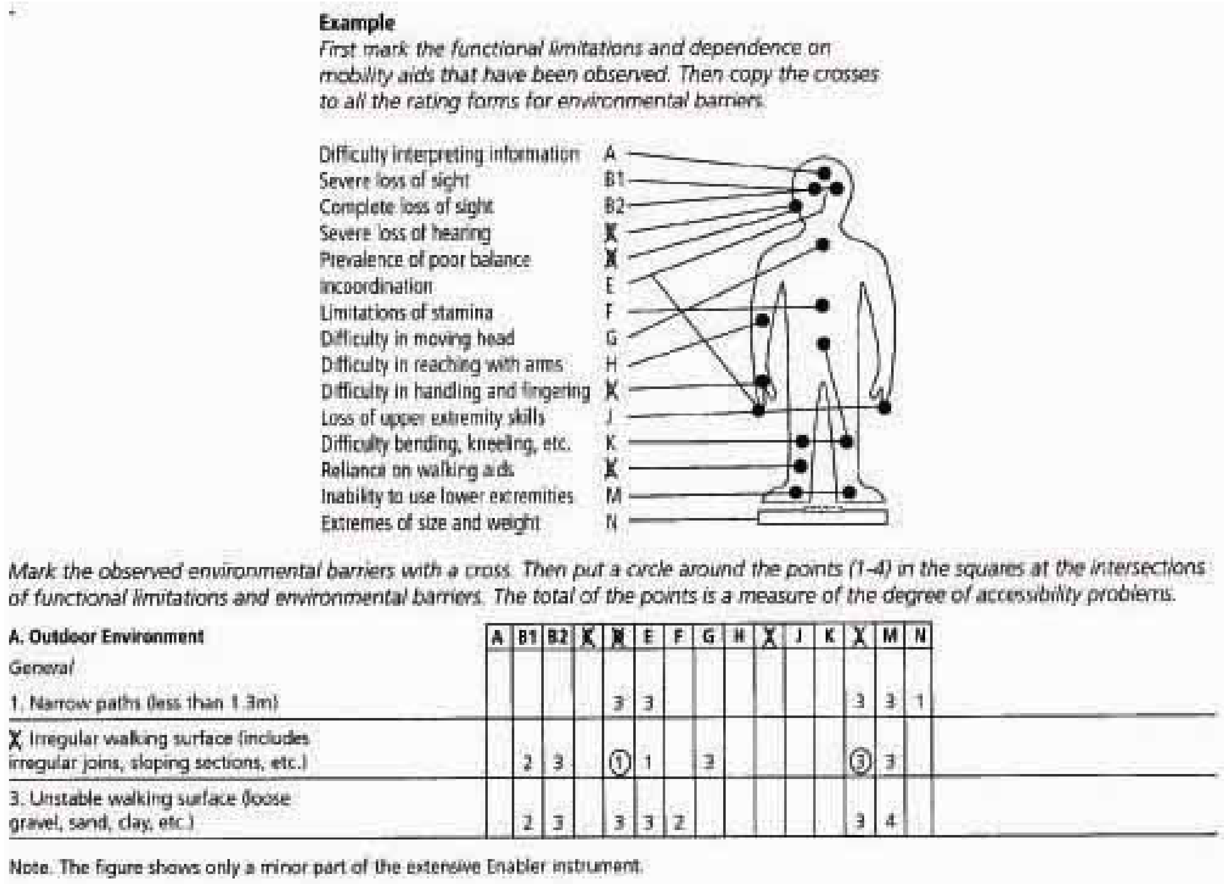

Figure 1 Example of the three administration steps for assessment with the Housing Enabler: (1) functional limitations and dependence on mobility aids assessed as present or not present; (2) environmental details assessed as present or not present; and (3) the information in steps 1 and 2 is used. By means of the scores 1–4 in the matrices a total score predicting the degree of accessibility problems can be determined. Copyright © 1999, *The British Journal of Occupational Therapy*, reprinted by permission.

Fig. 1 Concept of Enabler model (for a house)

extracted from Jensen *et al* (2002)

Central to this research was the establishment of the scale for the accessibility problems. Regarding their scaling, there may be two points to be discussed here: a) adequacy of the aggregation of scores and b) consistency among raters (those who evaluate accessibility problems with the instrument). Before discussing, let's look at how this enabler model measures the accessibility problems. As this paper has seen in Fig.1, each possible environmental problem against the related body function is evaluated using the score of 1-4: 1 for "potential problems", 2 for "problems", 3 for "severe problems" and 4 for "impossibility" (Iwarsson and Isacsson (1999)). These scores were pre-evaluated by researchers. The first point for discussion is the adequacy of the aggregation of the scores. According to this Swedish model, the scores in the matrix can be summed up to show the degree of the accessibility problem in total. However, a possible question here is whether it is suitable to aggregate different problems, such as blindness and problems with legs, and whether the summed up score comprehensively represents the severity of the accessibility problem. It is theoretically possible that those who have many minor accessibility problems show the same score as those who have a few big accessibility problems. The second point is consistency among raters (Law (1987)). Bias among the raters is unavoidable in this kind of evaluation.

It is acknowledged that these scaling problems are not unique to the Swedish studies, but common among medical or occupational studies evaluating disability (i.e. Law (1987)). The very nature of these problems originates in using indices (or categories) created by researchers. This is because the aim of these studies is to overlook the severity of accessibility problems in a simple manner, and therefore these studies employ researcher-defined simple indices or categories.

However, in order to integrate the evaluation of accessibility into the planning/design of transport facilities, the evaluation should be more practical. The output of the evaluation should be represented with established numerical indices that can be comparable with other indices. One example of the output can be monetary indices that make possible cost/benefit analyses.

β) Cepolina and Tyler (2004)

Cepolina and Tyler (2004) proposed a detailed model that can represent the mechanism of accessibility problems. To describe the mechanism, Cepolina and Tyler introduced the capability model. According to this capability model, a person has a set of unique capabilities for body functions, such as the ability to see, and the environment has a certain requirements for body functions for a person to use a facility/service. The capability of a person is called "provided capability", and the capability the facility (the environment) requires is called "required capability". Whether a body function can be executed or not is determined by comparing both the provided capability and the required capability.

For example, if a pedestrian climbs a step, the step requires a set of body functions, such as "raising a foot". Suppose the height of the step is 30cm. In this case, the stair requires that the pedestrian be able to raise a foot (more than) 30 cm (= required capability). If the capability of the pedestrian to raise a foot (= provided capability) is 25cm, this body function (raising a foot) is not executable. If it is 40cm, it is executable. (However, in order to climb the step, other body functions to climb a step, such as “recognising the step”, should be executable as well.) Fig.2 is a schematic representation of the capability model by Cepolina and Tyler (2004).

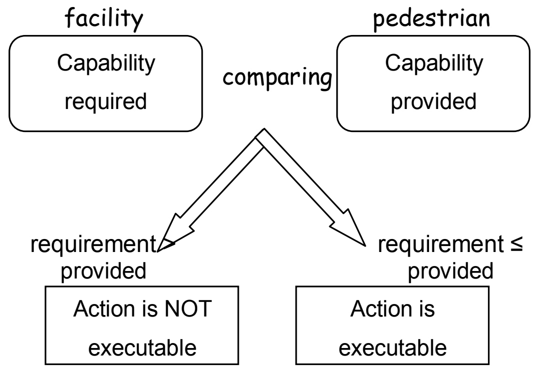

Fig. 2 Capability notion by Cepolina and Tyler (2004)

One strength of their approach was to look at only the result (output) of the action. The result has only two options: manageable (going ahead) or unmanageable (avoiding). Their research did not look at the difficulty to manage the facility (or the environment) with researcher-defined indices/categories in a medical/occupational manner. Consequently, the result is objective, and therefore the evaluation can be integrated to other indices used in planning/design of transport facilities.

In fact, their intention was to juxtapose the results with the demographic distribution in order to see how many people in the population can/cannot manage the given facility (or the environment, service) (Tyler (1999)). This brought two benefits. One was that their approach can exclude the bias amongst raters because the approach didn’t use researcher-defined scales/indices. The other benefit was that by using demographic distribution, this approach can discuss the accessibility at a more practical level. For example, if a bus service can cover 90% of the targeted population, it is necessary to prepare another special service for rest of the population. In order to offer such a special service to cover the rest of the population, it should be recognised how many people are entitled, a rough idea about its operation cost, and so forth.

One point toward which Cepolina and Tyler might go further is to provide a more detailed picture of a practical application of this model. They didn’t show how they prepare such demographic data and develop a list of body functions. Also, it should appear in a later research how to investigate whether a person can manage the given facility (or the environment).

Studies in this Conjunction approach can be regarded as attempts to develop a new framework for the analysis of accessibility problems by taking account of factors of both people and the facility (environment). This paper has looked at two approaches in this category. Both of them are under development, and the results of their practical application of their proposed model have yet to appear. However, there may be three points to be discussed in order to go further from these studies.

First point is how to define the targeted people of accessible transport facilities. Both Swedish studies and Cepolina and Tyler stressed that accessibility problems should be discussed based on the combination of human and environmental factors. Cepolina and Tyler especially illustrated that disability occurs when the provided capability of a person is less than the required capability of a facility (environment). On the other hand, the facility (environment) is not consistent. The facility (environment) varies according to where a person goes. This suggests that it is impossible to pre-define a certain people as disabled because the facility (environment), which is one factor to decide "disabled", is not consistent. We had better consider all people with the diversity and examine the accessibility for each person at each time.

Second point is that a barrier is not a problem that has only two answers: manageable or unmanageable. In the model of Cepolina and Tyler (2004), when a person confronts a new facility (a new environment), he/she judges whether the facility (environment) is "manageable" or "unmanageable" by comparing two capabilities: the provided capability and the required capability. If manageable, he/she continues his/her action as the same way before. If unmanageable, he/she avoids the facility (the environment). However, there may be many people who can manage the given facility (environment), but have/feel difficulty in managing it. For example, imagine an underground station having an unusually large gap between a vehicle and a platform. (i.e. Bank station in Central line of London Underground). There may be some people who can physically go over the gap, but have difficulty going. If the track and platform were reconstructed and the gap disappeared, such people could get on/off the train with more easiness. In order to fully capture the benefits of accessible facilities, such increased easiness should be taken account of. In other words, this manageability of a person toward a facility should not be regarded as a discrete problem that has only two answers: manageable or unmanageable.

Third point is what the results of analysis mean. Swedish model can describe the severity of the accessibility problem in a medical/occupational manner, which use researcher-defined indices (categories). However, we don't know whether we can aggregate different accessibility problems by simply summing up scores of such indices. Cepolina and Tyler did not mention the details of the output of their model. It is understandable that these studies have not precisely mentioned the result or the practical application of their model because these pilot studies should be appraised largely by proposing a new theoretical framework to combine previously unrelated factors. However, in order to perform the evaluation of the accessibility in the planning/design of transport facilities/services, outputs of the evaluation should be practical.

The three points cast here are discussed in the next section.

3. Basic notion of the proposed model

3-1. Introduction

This section considers what premiss are necessary in order to develop a new evaluation model. Evaluation of accessibility may vary according to where or what kind of accessibility is examined. The model is designed to evaluate accessible designs in large public transport facilities, such as underground stations or railway termini, because in such facilities ordinary people, as well as elderly and disabled people, use accessible facilities and indeed accessible facilities bring benefits for all users.

In the model, following two aspects are especially considered..

a) All people can be beneficiaries of accessible facilities.
b) Manageability of a person toward the facility (the environment) is not discrete but continuous.

This paper closely looks at each point in the following sections,

3-2. Beneficiaries of accessible facilities

As this paper has seen in section 2, it is intractable to pre-define those who require accessibility because the mechanism that causes accessibility problems does not always make the same people disabled but makes a variety of people disabled according to the facility (the environment) people confront. Also, this paper has confirmed that ordinary people also receive the benefit of accessible facilities. This infers that when evaluating accessibility, we should consider all population with diversity. It is also assumed that each person has his/her unique characteristics, and therefore he/she reacts toward a facility (environment) in his/her unique manner being different from that of other people.

3-3. Manageability of a person toward the environment

As this paper has seen, there may be many people who can manage the given facility (the environment) but with great difficulty. For example, Steenbekkers and Beijsterveldt (1998) investigated manageable heights of a step for elderly people. Suppose a person's maximum manageable height is examined. A question is if a vertical gap between the platform and the vehicle in a bus-stop is a bit lower than this investigated maximum manageable height, can he/she normally use the bus-stop? This paper assumes that the answer may not be always "yes". He/she may answer that "The gap is certainly manageable, but for me going over the gap is still a hard and tiring job, so that I feel some hesitation to use the bus-stop."

In fact, hitherto accessibility problem has been considered as a discrete problem where the concern is whether a person can physically manage or not. But for a user, although the provided facility (environment) is physically manageable for him/her, if the facility requires a hard, tiring or complicated task, the person feels difficulty and consequently he/she doesn't so often use the provided transport facility (such as a bus-stop or a bus system).

This paper assumes that the less requirement of the facility (the environment) for a person to pursue a task, the more easily the person can manage the facility (the environment). In the example of a vertical difference between a bus vehicle and a bus-stop platform, this paper assumes that the lower the height of the difference, the more easily people can manage the difference. In other words, this paper regards accessibility problem not as a discrete problem (i.e. whether the height is manageable/unmanageable for a person), but a continuous problem

(i.e. the better accessible design, the more easily people can use.)

This approach also helps to widely recognise the benefit of accessible facilities. Poor design causes some unnecessary reactions for all people including those who are robust and can manage the design. On the other hand, all people can easily use facilities with well-accessible design.

4. Description of the proposed evaluation model

In this section, this research develops an evaluation model derived from the premiss in section 3.

4-1. Coping model

This section considers a new model with which we can capture the phenomenon that accessible facilities/services are of benefit not only to elderly or disabled people but also to ordinary people. The model shown here is a simplified version of the “dealing model” in Fujiyama (2003).

Suppose a single vertical difference with the height of 20cm on a floor in a railway station. A person may be able to go over it, but he/she may also feel disturbed or annoyed by the vertical difference because he/she has to pay attention or change his/her step sequence or whatever.

Next, suppose another vertical difference with 5cm height and compare it with the 20cm-height difference. Presumably, the person feels easier to go over the 5cm-height difference than 20cm. We can assume that the lower the vertical difference, the easier he/she feels. This implies an inverse proportional relation between the easiness and the height of the vertical difference. Fig. 3 is a schematic representation of this relation. The actual relation between the easiness and the step height might be more complicated than one in Fig. 3, but this research simplifies the relation as shown in Fig. 3.

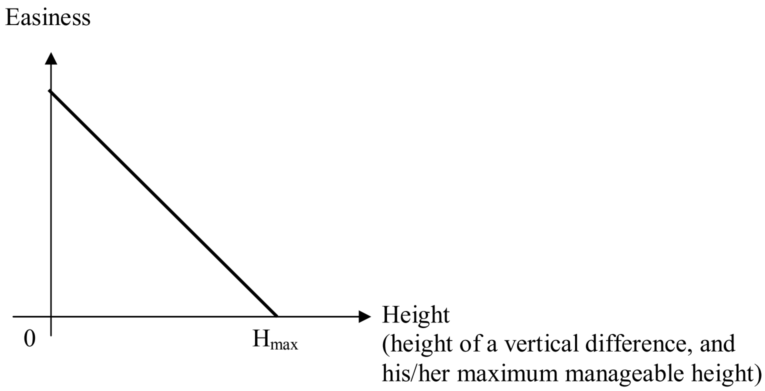

Fig.3 Relation between easiness and the height of the vertical difference

H_{max} means a unique maximum manageable height of the vertical difference for a person. If the height of a vertical difference is higher than this H_{max}, the person cannot go over the difference. If the height of the vertical difference is lower than this H_{max}, he/she can go over it, and the less the height of the difference, the more easily he can manage it.

This paper also assumes that a curb for the relation in Fig. 3 may vary amongst people. The maximum height of a robust young man may be higher than a middle aged person. The maximum height of an elderly person may be less than a young person. Also, easiness may vary according to how each person manages the difference. This infers that each person has his/her unique curb for the relation between the height of a vertical difference and easiness to go over it, as Fig. 4 displays.

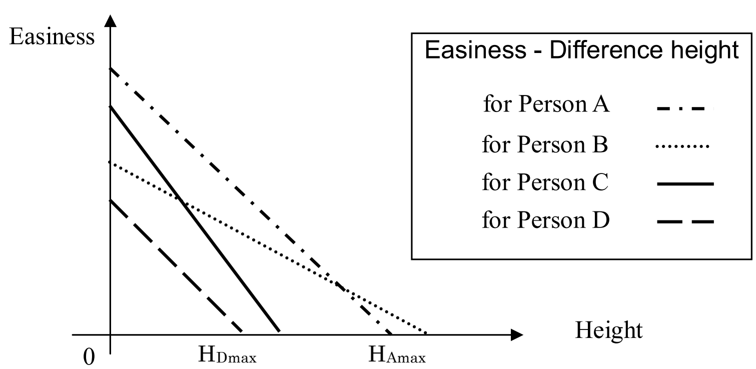

Fig.4 Relation between the height of the vertical difference and the easiness of a variety of people

In Fig. 4, if the height of a vertical difference in a station (H_{real}) is around H_{Amax}, Person D cannot manage the difference. If that vertical difference is just below H_{Dmax}, Person D can go over it and also Person A can go over the difference more easily than the case where the height is around H_{Amax}. This suggests that if the height is lowered to the level where frail people such as elderly or disabled people can manage, ordinary people gain more easiness or usability. The lower the height required by the facility, the more benefit people can receive.

This model can be expanded to other accessibility problems, such as the distance from home to the nearest bus stop. In this case, the height in Fig. 3 is replaced by “the distance to a bus stop.” Suppose a situation where the distance to a bus stop is about 1,000m. This may exclude some frail people whose limit of walking is just 100m. Providing that the bus network is redesigned so as to reduce the distance to 100m, they can join the bus system. If the distance is 30m, the frail people can more easily reach the bus system.

It may be reasonable to generalise this relation between the height and the easiness. Instead of the height, “Environmental requirement” can be employed in Fig. 3. Environmental requirement means the dimension that shows the degree of the requirement of the facility (environment) for a person to manage it. Also, “Easiness” can be interpreted as the easiness for a person to manage the given facility (environment).

4-2. Description of the diversity of people

In the section 3, this paper discussed the necessity to consider all people with the diversity including elderly and disabled people. As this paper has seen in Fig 4, each person has a unique maximum height and a unique curve for the relation between the environmental requirement and the easiness. In order to discuss further, this paper now considers how to describe the diversity of people.

Both Swedish studies and Cepolina and Tyler (2004) made use of a set of attributes in their model to describe people with the diversity. In Swedish studies, attributes were functional limitations, such as “severe loss of sight” or “difficulty in moving head.” In Cepolina and Tyler, attributes were “capabilities”, such as ability to see and so forth. The proposed model follows the idea of Cepolina and Tyler.

4-3. Output of the evaluation

The last section has shown that as we reduce the environmental requirement of the facility (in the previous example, the height of the vertical difference), easiness (to use the facility) increases. In the evaluation model, in order to capture the easiness, this paper focuses on the actual and consequent behaviour of a person who confronts a facility. This paper assumes that this consequent behaviour reflects "easiness" a person achieves.

In order to grasp a clear picture of this "actual and consequent behaviour", a simple example is examined here, where a person approaches to a single vertical difference on a flat surface. He has his unique maximum climbable height (H_{max}) for a vertical difference. The less the height of the step, the more easiness he gains (i.e. easiness to go over the difference). If the actual height of the difference is H_{given}, he gains the corresponding easiness (E_{given}). Fig.5. shows this mechanism.

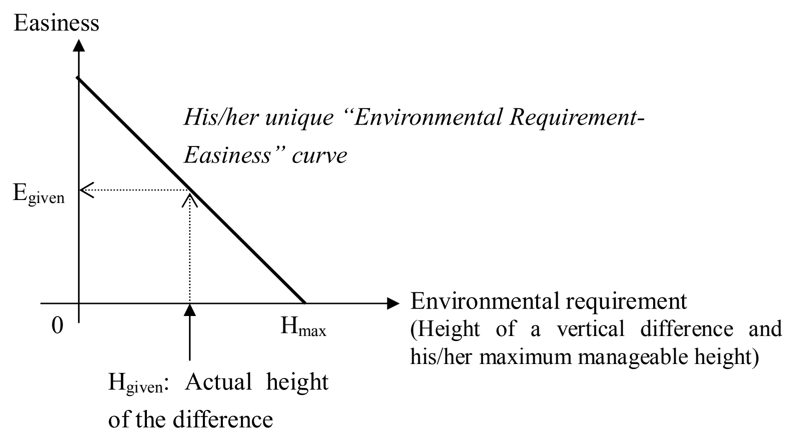

Fig.5 Mechanism of accessibility in the given environment

However, easiness is a conceptual index. As medical/occupational studies have shown, it may be intractable to measure this kind of researcher-defined indices. It is required that results of the evaluation be described by established indices that can be used in the planning/design of public transport facilities. Using established indices makes it possible to combine accessibility problems with other issues in planning/design of transport facilities. Indeed, in the planning/design of accessible facilities, accessibility is not an independent design problem (i.e. what shape is the best), but a problem related to other issues, such as creating space for the accessible facilities or the construction cost.

It is presumed that the actual/consequent behaviour of a person toward a vertical difference corresponds with this easiness the person achieves.

$$\text{Actual/Consequent behaviour} = f(\text{easiness})$$

There may be several indices for the actual and consequent behaviour, which can represent the easiness a person achieves. Fig. 6 is a schematic representation of this notion.

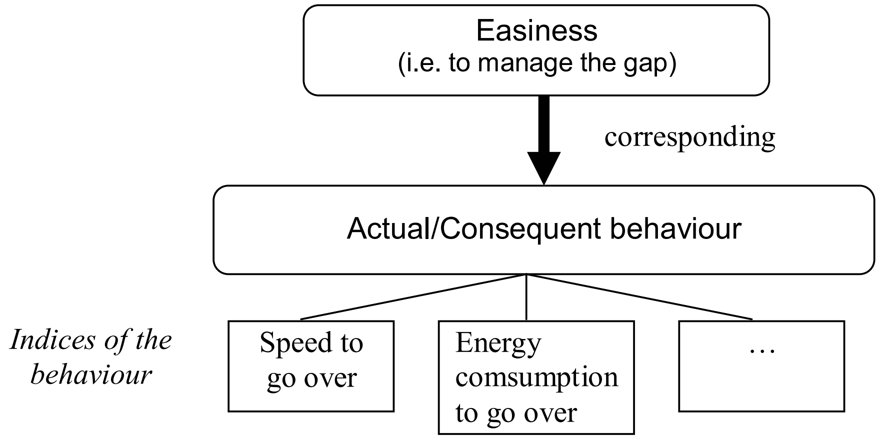

Fig.6 Relation between accessibility and actual/consequent behaviour

For instance, let's take his/her walking speed to go over the difference as the index of actual/consequent behaviour. If the height of the difference is near 0mm, he can go over fast. If the height is nearly his maximum climbable height, his speed to go over the vertical difference is very slow. Fig. 7 shows this mechanism. (The relation may not be such a clear linear one, but for simplification this paper assumes a linear relation.)

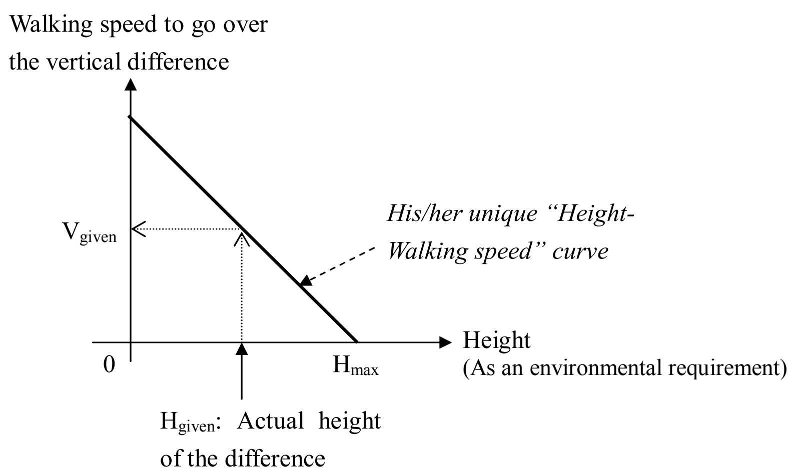

Fig.7 Mechanism of height- actual/consequent behaviour

(Relation between walking speeds and heights of the vertical difference)

4-4. Comparison with other approaches/studies

a) Comparison with the capability model by Cepolina and Tyler (2004)

Coping model may belong to the Conjunction approach between people and facilities because the model consider both human and facility (environmental) factors. Cepolina and

Tyler (2004) also showed a similar model called “capability model.” This sub-section considers the difference between the coping model and the capability model. Fig. 8 is an extraction from Cepolina and Tyler (2004). X-axis means difficulty for a person to do (achieve) a certain action. Y-axis means the capability related to the action. This capability is an abstract index to describe the ability of the human physical system. Each person has a unique “personal (provided) capability level” for the action represented as A_1. On the other hand, the required capability by the facility (environment) increases as the difficulty in achieving the action increases. If the required capability surpluses the personal (provided) capability, the action become non-executable.

For instance, suppose a person going over a step. In this example, the height of the step can be X-axis as the representation of difficulty in going over the step. Y-axis means the capability to go over the step. The person has a certain limit for going over the step, described as A_1. As the height of the step increases, the required capability to conduct an action “going over the step” increases. If the height excesses the point A, from which the required capability surpluses the personal provided capability, the person cannot pursue the action “going over” toward the step with the given height.

The easiness, determined by coping model, can be plotted out as the difference between the personal provided capability and the required capability. This infers that, in the example of going over a step, the less the required capability (the height of the step), the more easily a person can manage the step. Also, the model infers that the more capability a person has for going over the step, the more easily the person can manage the step.

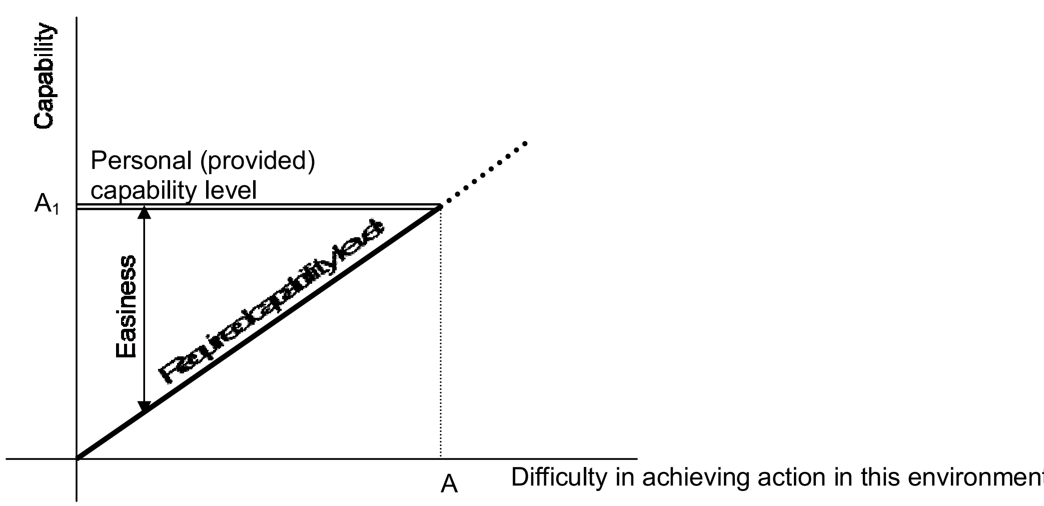

Fig.8 Easiness and Capability model proposed by Cepolina and Tyler (2004)

(produced based on Fig.3 in Cepolina and Tyler (2004))

b) Comparison with other studies

The strength of the coping model is to objectively look at how a facility (or environment) affects people. Fig. 9 performs comparison of coping model with other studies. The left column means the environmental factors or environmental requirement. The centre column indicates human factors or the physical system inside the body. The right column displays the actual/consequent action or output of the result. For simplification, this paper ignores minor differences between studies, and the terminology of each study is rearranged according to the terms in this paper.

People oriented approach only concentrates on human factors or inside the body. So-called medical models for the disability (i.e. WHO (1980)) can be categorised here. On the contrary, Facility/service-oriented approach and so-called social models for disability (i.e. Oliver (1994)) look at environmental factors. Jensen *et al* (2002) can be interpreted as an attempt to look at both environmental factors and human factors. Cepolina and Tyler (2004) moved the research focus to the actual/consequent action as a result of comparison of capabilities. Their way to see results is whether a person can manage the given facility (environment) or not. In other words, they took a binary approach (can/cannot). This research regards actual/consequent actions not as binary but as continuous. The output is numerous corresponding with the easiness determined by the degree of the difference between the provided capability and the environmental requirement.

5. A pedestrian simulation as a practical application tool of the proposed evaluation model

5-1. Introduction

This section looks at a pedestrian simulation developed in the light of the coping model.

There may be several ways to materialise the coping model into a practical evaluation. Note that there has been no established practical/numerical tool for the evaluation of accessibility. Here, this paper shows one attempt to develop a practical/numerical tool derived from the coping model. In the course of developing this practical application tool, following four points are considered in order to give a clear shape to the tool.

a) Target of the evaluation
b) 5-3. Description of the environmental requirement and the easiness

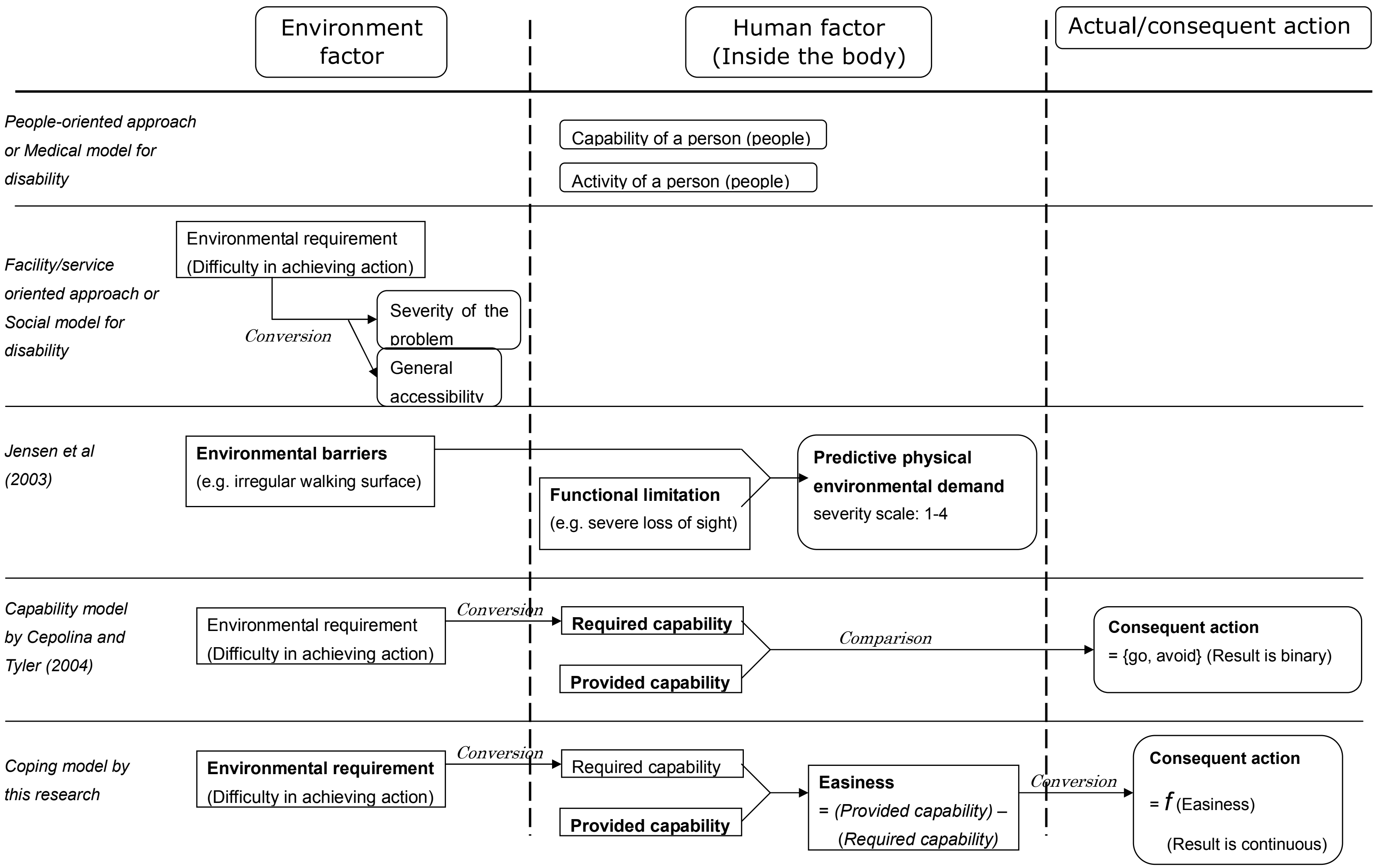

Fig. 9 comparison of evaluation models

c) Description of the diversity of people
d) Simulation details

5-2. Target of the evaluation

The intention of this study is to evaluate the accessible designs in large public transport facilities, such as underground stations or air ports. The most serious problem in such transport facilities may be vertical differences in facilities. For railway systems including the underground, gaps between the platform and the vehicle, or a large number of stairs between the platform and the entrance prevent many people from using the facilities.

The ideal solution for this problem is to make all stations step-free. For instance, London Underground is now increasing step-free access stations (London Underground (2002)). On the other hand, the studies on stairs are also necessary in order to capture the benefit of the step-free station by comparing step-free stations with non-step-free stations. Also, given that there have been few studies on the movement or mobility of people on stairs, there should be more research on stairs. Therefore, this paper concentrates on pedestrians' movements on stairs.

The focus of this research is how a variety of people react different kinds of stairs. Our interest goes especially to the behaviour of elderly people, whose percentage amongst the population is rapidly increasing. (In the United Kingdom, the proportion of the people aged more than 65 was 16% in 1996 and in 2001, but will be 19% by 2021 and 25% by 2041 (Age concern, 1999). Similar increases are expected in most other countries in the world.)

5-3. Description of the environmental requirement and the easiness

Coping model is applied to movements of people on stairs. This study chooses the stair-gradient for the index of the environmental requirement. This is because we assume that the tread-length and the riser-height are important indices of the characteristics of stairs, and that stair-gradient is an index that combines these two indices. This paper also chooses the walking speed on stairs for the index for the actual/consequence behaviour reflecting the easiness. The benefit of the walking speed as the index is that this index is related to or comparable with other indices used in the planning and design of large public transport facilities, such as the capacity of the facility or the construction cost.

5-4. Description of the diversity of people

Both Cepolina and Tyler (2004) and Swedish studies employed a set of attributes to describe the diversity of people. This idea seems reasonable. However, in practice, using many indices (representing functional limitations or capabilities for body functions) makes the proposed evaluation tool complicated. For simplification, this paper employs only one index that represents the capability related to walking on stairs.

Physiological studies have shown that leg extensor power (LEP) is related to walking characteristics of people. Bassey (1992) showed that LEP was correlated with the walking speed. Levy *et al* (1994) suggested that confidence of being able to step up a certain height of a step is related also to LEP. They concluded that "to be confident of being able to step up 30 and 50 cm requires a power/weight ration of at least 1.5 W/kg and 2.5 W/kg respectively," where "W(watt)" is the unit for LEP and "kg" is the unit for the weight of participants. (Detailed review of these physiological studies can be seen in Fujiyama and Tyler (2004).) Based upon this knowledge, this paper picks up LEP as the index of the proposed evaluation tool.

The benefit of employing LEP as the index is that there was a national survey that investigated LEP, as well as other physical and anthropometric indices, across a large sample of the general population (Sports Council *et al* (1992)). This makes it possible to evaluate accessible facilities based on the national population.

5-5. Simulation details

Proposed evaluation tool takes the simulation approach because this research considers a variety of people in the evaluation. Also, the interest of this research is in the output of interactions between a variety of facilities (environment) and various people. In order to describe such a complicated situation, simulation may be a good approach for this research.

Proposed pedestrian simulation can represent the interaction between a facility (or environment) and capabilities of people, where both facilities and people vary. The form of the proposed simulation is a microscopic simulation, where each pedestrian is modelled individually. Proposed simulation is derived from Cepolina and Tyler (2004), which developed basic interaction rules between pedestrians and facilities (environments). The advances made in this research from Cepolina and Tyler are that the simulation of this research regards the output of such interactions as continuous, whereas Cepolina and Tyler regarded as discrete. Also, the proposed simulation has practical shapes, and integrates the empirical data shown in section 6.

The output of an interaction between a pedestrian and a facility appears as the walking speed of the pedestrian on the facility. Fig.8 is a schematic representation of this notion.

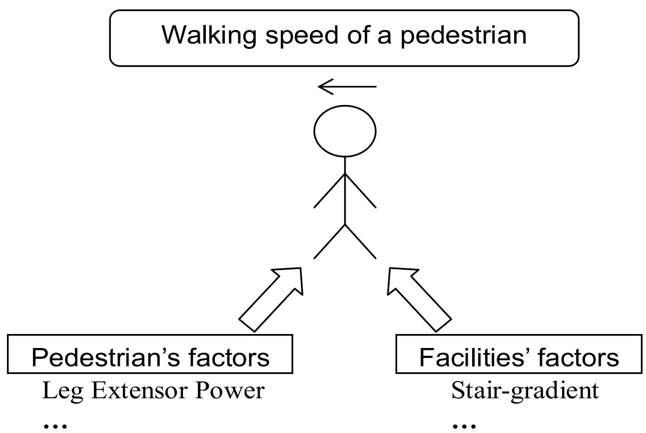

Fig 8. Schematic representation of the walking speed of each pedestrian

In order to examine the relation between stair-gradients and walking speeds of people, and the relation between LEP and walking speeds, this paper have conducted an experiment. The results are displayed in section 6.

6. A brief summary of the experiment

Based on the assumption in section 5, this paper has carried out an experiment. Here is a brief summary of the experiment. (Details of the experiment can be seen in Fujiyama and Tyler (2004).)

The first experiment was conducted to explore the relationship between walking speeds of people on stairs and stair-gradients. The participants were categorised into two groups, namely Group 1: (6 healthy men and 12 healthy women, aged between 60 and 81) and Group 2: (7 healthy men and 8 healthy women, aged between 25 and 60). Fig 9 shows the relation between stair-gradients and average ascending speeds of both groups at four sets of stairs with different stair-gradients (At each set of stairs, the participants were instructed to ascend stairs twice: at first at the normal speed, and secondly at the fast speed.) There may be a linear relation between horizontal or inclined speeds of ascending stairs and stair-gradients. Note that each participant showed a similar tendency in his/her own result. This coincided with the assumption that the environmental requirement (in this case, the stair-gradient) has a reverse proportionate to an output of the easiness (in this case, the walking speed). Compare Fig.9 with Fig. 7.

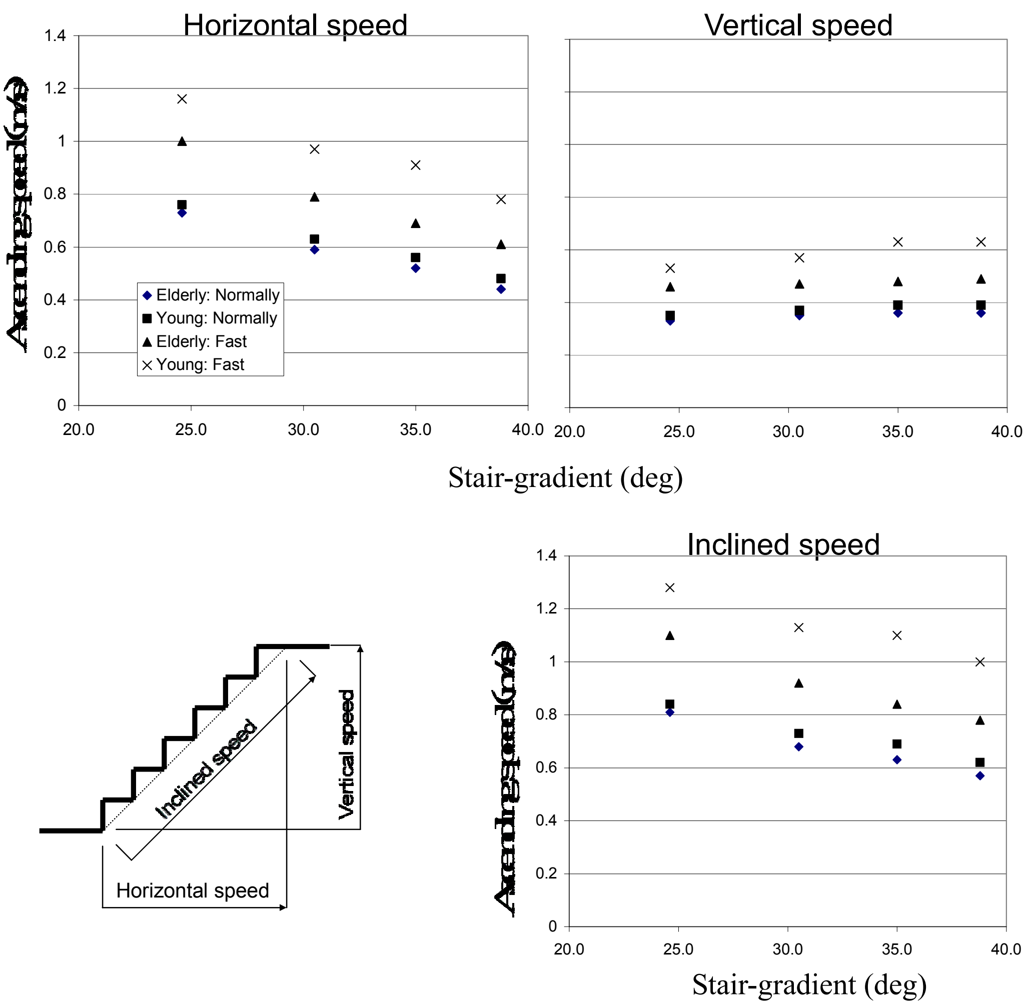

Fig.9 Relation between stair-gradients and ascending speeds:

Horizontal/ Vertical/ Inclined speeds

In the second experiment, how LEP (leg extensor power) is related to the walking speed was examined. Fig 10 displays the relation between LEP and normally ascending speeds (horizontal speed, Stair 2). For the elderly subjects, there may be a liner relation between LEP and the normally ascending speed (r=0.76), whereas for the young subjects, there may be a non-linear relation (r=0.17).

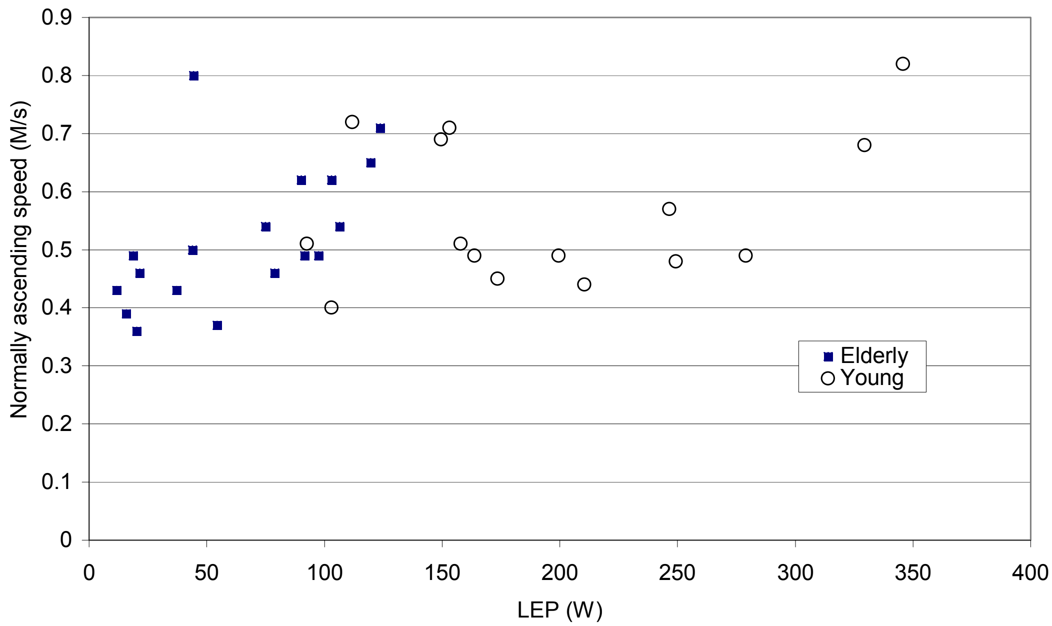

Fig 10. Relation between LEP and normally ascending speed (horizontal speed, Stair 2)

7. Conclusion

This paper presented an attempt to develop an evaluation tool for accessibility. The main concept is to consider that beneficiaries of accessible facilities are not only a certain people but also all people with the diversity including elderly and disabled people.

The proposed evaluation model called "coping model" focuses on "easiness" of a person to manage a facility (environment). This paper assumes that the less "environmental requirement" the facility requires, the more "easiness" a person can achieve. A pedestrian simulation was also proposed as a practical application tool of the coping model. The simulation concentrates on movements of people on stairs. A brief summary of an experiment that provided empirical data to this model was displayed as well.

This paper thinks that accessibility is not something that provides or guarantees the transport usage for a limited number of people, but something that makes the facility/service more friendly to all people including elderly and disabled people. The author wishes that the attempt of this research could find more benefits of accessible facilities than currently estimated, and consequently this research could encourage more introduction of accessible facilities.

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