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EVACUATION SAFETY FOR LOCOMOTION DISABLED PEOPLE

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SUMMARY
People are most of the time expected to evacuate by themselves in an emergency situation. The design of escape routes today does not make it possible for all people to do so. To investigate the safety of locomotion disabled people, in case of an evacuation, a serie of experiments were conducted. The experiments were performed to identify and quantify factors that can influence the evacuation for locomotion disabled people. The aims of this study were to investigate both the locomotion disabled peoples possibilities to evacuate by themselves, and the fire departments possibilities to assist the locomotion disabled.

BACKGROUND
A bill proposed by the Swedish Government (regeringens proposition 1999/2000:79), once again, brought the question of disabled peoples safety in case of an emergency evacuation into daylight. A fire department in the south of Sweden (Raddningstjansten Vastra Blekinge) got a request whether it was possible to have classrooms for disabled people on the second floor, in terms of egress. Together with the Swedish Rescue Services Agency the fire department started a project concerning locomotion disabled peoples possibilities to a safe evacuation.

The project only included locomotion disabled, able-bodied and only public buildings were studied. All of the locomotion disabled were older than 15 years and unassisted.

Participants were fire safety engineer students, fire safety engineers, an accessibility consultant, a human behavior scientist, an organization for disabled people (Handikapporganisationerna i Blekinge), a fire department (Raddningstjansten Vastra Blekinge), the Swedish Rescue Services Agency, the Department of Fire Safety Engineering at Lund University and voluntary locomotion disabled people.

CONDUCTED EXPERIMENTS
To investigate locomotion disabled people's safety in case of an evacuation, several experiments were conducted. Factors that might influence the evacuation time were studied in five experiments. In total 90 volunteers participated in one or more of the experiments, out of these 50 had different locomotion disabilities.

In the experiments the participants were divided into four different categories:
Category 1) able-bodied
Category 2) ambulant with locomotion disability
Category 3) manual wheelchair user
Category 4) electric wheelchair user

To get a reference group, category 1 able-bodied, were studied. This group is usually used when dimensioning escape routes.

Escape route
This experiment was made to investigate locomotion disabled peoples possibilities to evacuate by themselves. Factors such as movement speed up and down ramps and on horizontal ground were examined as well as the time and space needed to turn. The influence of threshold heights and the needed opening force to pass through a door were also investigated.

A total of 48 people participated in these experiments, 12 from category 1, 9 from category 2 12 from category 3 and 15 from category 4.

In an evacuation situation it is crucial to be able to change direction while evacuating. Most escape routes involve corridors and to investigate locomotion disabled peoples possibilities to change direction, the participants were asked to turn 180 degrees. The results are shown in figure 1.

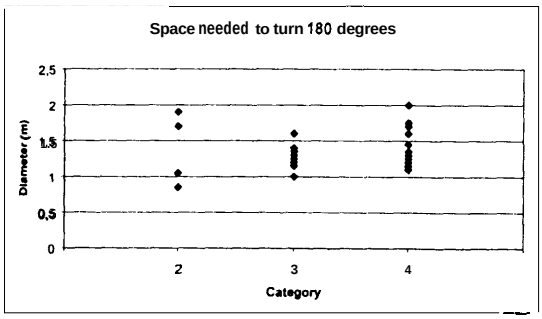

Figure 1 *Space needed to turn 180 degrees*

Movement speed up and down a ramp and on a horizontal surface was examined as well as the time needed to turn 90 degrees. The ramp was 1,2 meters wide and six meters long, the inclination was 1:12. Movement speed on a horizontal surface was measured over a distance of 31 meters. The width of the turn was 1,2 meter. Results of the movement speeds are depicted in figure 2, 3 and 4.

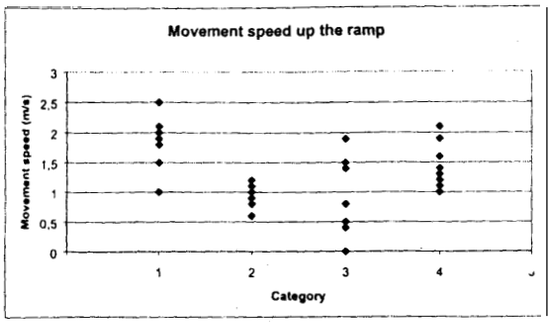

Figure 2 *Movementspeed up the ramp*

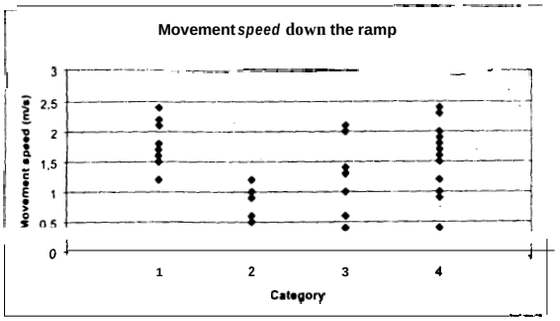

Figure 3 ***Movementspeed down the ramp***

Five out of the twelve participants using a manual wheelchair found the ramp to long/steep and therefore failed. Down the ramp three out of the twelve participants using manual wheelchair failed. In figure **2** and **3** they are denoted as having a speed of 0 meters per second. The average movement speed for the ambulant locomotion disabled is the lowest, it is about half the speed of the able-bodied.

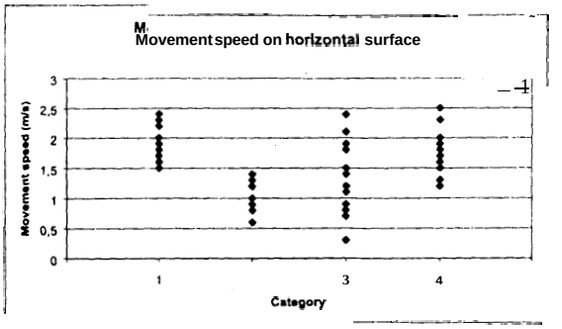

Figure 4 ***Movementspeed on horizontal surface***

The influence of threshold heights and the opening force needed to pass through a door by pushing it open were investigated. In this experiment only locomotion disabled participated because it was their possibilities to pass through a door that was of interest. In total **six** experiments were conducted for each participant with opening forces of 40 or 130 Newton and threshold heights of 0, 2,5 or 4,0 centimeters. To pass through the door the participants

did not have to push down the door handle. Both the threshold height and the opening force caused problems for the participants as shown in table 1. If the participant did not manage to open and pass the door by him-herself it was classified as a failure.

Category	Threshold height (cm)	Opening force (N)	Number of participants	Number of failures
3	0	130	12	2
3	2,5	40	12	3
3	2,5	130	12	2
3	4	40	12	7
3	4	130	12	6
4	4	40	4	1
4	4	130	4	1

Some of the participants who were using walking frame and manual wheelchair had problems when they had to maneuver, move their aid forward and at the same time open the door.

Evacuation aided by firemen

This experiment was conducted to assess how firemen best could help manual wheelchair users in evacuation situations. The evacuation route included stairs up and down, a corridor and 90 degree turn. Three experiments were repeated eleven times with different participants. In the first experiment two firemen assisted a person sitting in his/her wheelchair during the whole experiment. In the second experiment two firemen assisted the manual wheelchair user by carrying him/her through the evacuation route. In the final experiment one fireman assisted the wheelchair user sitting in his/her wheelchair through the evacuation route.

The results imply that, due to the time aspect, if the escape route contain stairs it is better to carry the evacuee out. In horizontal escape routes without narrow passages no time is gained by carrying, instead of pushing, the manual wheelchair user. There was no relevant time difference between the first and the third experiments. After the evacuation the fireman who evacuated the wheelchair user by himself was more exhausted than the two colleagues were in the first experiment.

Evacuation by elevator

This experiment was made to investigate the possibilities for mixed populations to evacuate by elevators. Only the time aspect was studied. It was conducted two times with two different populations. In both of the experiments a total of 33 people participated. In the first experiment only people from category 1 and 4 was represented, one third from the latter. The second population included people from all four categories. The time was measured from when the first person entered the elevator until the last one did exit the elevator one level down.

It took about six minutes for the first population and nine minutes for the second to evacuate. In the first experiment the population knew each other and was familiar with the elevator. This first experiment was also well organized, thus leading to a more efficient use of the elevator.

Evacuation by elevator is time consuming. It takes time both for the elevator to move up and down and for the evacuees to move in and out of the elevator. Locomotion disabled people

often need more space than able-bodied in elevators due to their aid. Many of them also need both time and space to maneuver in and out of the elevator.

Movement through passages

To investigate the occupant flow through passages this experiment was conducted. A mixed population was studied while moving through passages of difterent length and width. The width was 1,1 or 0,8 meter and the length was 1,1 or 0,02 meter. The occupant flow was studied both for populations consisting of only able-bodied, only locomotion disabled and mixed populations. The occupant flow for mixed populations, with different proportions of locomotion disabled people, was also studied in a passage with a length of 1,1 meter and a width of 0,8 meter.

The flow through passages decreased when the percentage of locomotion disabled people in mixed populations increased. The decrease was linear and in figure 5 the results from the final experiment are shown. Neither the width nor the length of the studied passages had substantial influence on the occupant flow of mixed populations in conducted experiments. **A** single slow individual could delay the evacuation completely or partly for the rest of the evacuees.

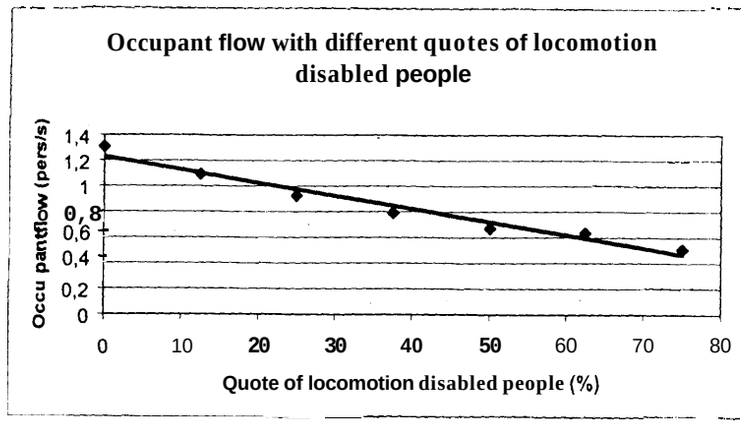

Figure 5 *Occupant flow*

Evacuation by ladder engine

Another set of experiments did investigate the possibilities for the fire department to assist locomotion disabled people from floors above the ground level by ladder engine. Previous to the experiments a short education in carrying-technique was carried out to avoid injuries both on the participating firemen and on the disabled people.

The experiment was conducted two times, each time with a different set of firemen and participants. Different ladder engines were used in the two experiments. The participants were evacuated from a balcony on the first floor. The ladder engine was in place ready to start the evacuation when the experiment begun.

In both experiments ten locomotion disabled people participated as well as ten able-bodied. **All** four categories were represented.

It took 30 respective 40 minutes to evacuate the ten locomotion disabled. Not all locomotion disabled people was able to stand on their legs and therefore they had to sit while being brought down. The evacuation of the ten able-bodied took two respective ten minutes.

The evacuation was both personnel intensive and time demanding. The personnel had to help the evacuee both in and out of the basket. The firemen, who participated in the experiments, stated that they had use of what they had learned in the previous education in carrying-technique.

PROBLEMS THAT MAY OCCUR

In evacuation situations where locomotion disabled people are involved several specific problems may occur. Before trying to lift and carry a person sitting in an electric wheelchair it is important to remember to turn the wheelchairs electricity off. It is also important how to carry locomotion disabled, when improper carrying- and lifting technique may lead to spacticity and injuries. All straps and belts, which may hold the person in an upright position in the wheelchair, must be unloosen before trying to lift the person from the chair.

CONCLUSION

The evacuation situation for locomotion disabled people is complex. Ability and possibility to evacuate varies from one person to another and from one day to another. When dimensioning escape routes it is important to take individual differences among the population into consideration. No single solution will provide the whole population egress opportunities. A combination of different solutions will be required.