Summary

The hub-and-spoke principle used by airline companies offers the possibility to have more flights to more destinations at lower cost. The flights are scheduled in a number of time windows, in which ideally all incoming flights connect to all outgoing flights. The annual growth of passengers and flights has a heavy impact on the performance of airports. Therefore airports carry out expansion projects which result in modern airport terminals with walking distances exceeding comfort level. The increase in walking distances due to airport expansions may cause a risk in maintaining the Minimum Connecting Time (MCT). Increasing the MCT is not desirable for both the airport and the airlines, because it may increase the transfer times in the hub airports (Kusumaningtyas et al. 2007-a).

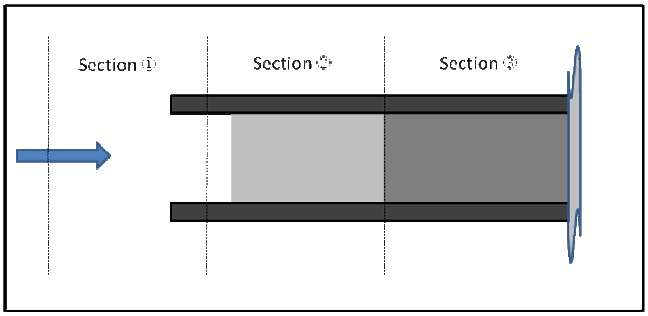
The installation of AMWs can be a useful in maintaining the MCT. A research is being carried out in Delft University of Technology to study AMWs, their applications and techniques. This study investigates two aspects: one, the implementation issues of AMWs in public facilities and two, the technical issues. For the technical aspect of the study, Kusumaningtyas investigated the application of distributed drive systems and the intelligent control of these systems. The goal is to minimize the wear and energy consumption of the system. For the implementation to be successful, it is important to have an accurate knowledge of the load on the belt in between the drives. The distribution of the load, the passengers, on the system is influenced by their behaviour. For a moving walkway, this is unknown. If there is an estimation of the practical capacity of an AMW, then there is a scientific base to ensure that the drives do not have to be based on its theoretical maximum capacity, because this is never reached. The main objective of this study is to find the practical capacity of AMW within airports and transfer stations.

In general the high speeds of AMWs vary between 1.5 m/s to 2.5 m/s. The difference between the entry speed and the high speed at the middle section of the AMW, namely the speed ratio, is up to four for the present installed AMW. The typical width of the treadway is between 0.80 and 1.2 m and conveyors with a width of 1.4 m are in development. The CEN set up a standard about both escalators and moving walkways in the NEN-EN 115 for different speeds and treadway widths. Some studies used different figures on how many people can stand on steps and some expanded the figures to larger widths or higher speeds. Taken together this results in a theoretical capacity of 4,500 P/hr at 0.60 m/s and 0.60 m width up to 20,250 P/hr at 0.75 m/s and a width of 1.4 m.

The capacity is commonly expressed in P/hr and is a multiplication of three parameters:

- The density in P/m^2
- The speed in m/s
- The width of the treadway in m

These parameters are used as input to calculate the practical capacity of AMWs. The parameters are dependent on each other and these relations are displayed in fundamental diagrams. The factors of influence on the capacity are categorized into three groups: factors when entering the system, factors while boarding and factors when on the conveyor. The sections ①, ② and ③ correspond with entering, boarding and standing on the conveyor.



The sections of an AMW

The distinction is made between microscopic and macroscopic factors in studies. The microscopic level concerns the individual characteristics of passengers. Factors are for example the trajectory, age, speed or human buffer zone of a person. The microscopic factors lead together to the macroscopic factors. The macroscopic level concerns the characteristics of the flow of passengers in total. The factors are used in calculating the practical capacity. The assumptions made are that passengers walk into the bottleneck, board the system from standstill and some of them want to walk and some keep standing still in ③. The rearrangements necessary in between are left out the study because no information is available.

The human buffer zone, as a microscopic factor, plays a role in every section of a conveyor: waiting in line, maybe going trough a funnel, entering the conveyor, walking or standing on it. It is a result of microscopic factors like size, speed, culture, gender, age, health and the perception of safety of individuals.
Two macroscopic issues used in this study are the layer formation in bottlenecks and the principle of a walk- and a stand side on conveyor systems. The formation of layers is the arrangement of people, walking through a bottleneck, in rows; they keep walking behind their predecessor. The passengers walk diagonally after each other and an overlapping of layers is present, called the zipper effect. The layer formation develops when the limit of the capacity is reached. There is a standing side (right) and a walking side (left) on conveyor systems. The space needed by and the total speed of passengers is different between the sides, this is taken into account in computing the practical capacity.

The practical capacity of the three sections is depicted in the next table. At ① the capacity is based on studies on bottlenecks. At ② the capacity at two common entry speeds of 0.6 and 0.75 m/s is based on figures of CMWs and stairs with phenomena occurring there. At ③ the capacity is calculated with two different high speeds: 1.5 and 2.5 m/s, with a side of standees and a side of walkers and the principle of formation of layers of passengers.

Overview of the capacity of the sections (P/hr)					
Width (m)	①	②		③	
		0.6 m/s	0.75 m/s	1.5 m/s	2.5 m/s
0.80	4,612	2,700	3,375	6,750	11,250
1.0	6,692	5,200	6,750	15,876	24,588
1.2	8,054	5,200	6,750	15,876	24,588
1.4	10,000	6,750	8,460	24,946	37,870

Capacity of the three sections

Section ② is the limiting one, independent of the entry speed of the AMW. The capacity of section ① reaches the level of ② closely. The results of the capacity at ③ for both high speeds are relatively high. The capacity with solely standing people is already high compared to the capacity in section ① and ②. This because the speed at ③ is two to four times higher and there are walking passengers. The speed is an incentive for passengers to decrease their walking speed so the capacity at ③ is probably lower than computed here.

The practical capacity of ② is expressed as a percentage of the theoretical capacity, see table. When the width of 0.80 m is left out the percentage is approximately 44%. References show higher figures on this but it is not verifiable because these are just indications.

Width (m)	Percentage (%)	
	0.6 m/s	0.75 m/s
0.80	33	33
1.0	50	50
1.2	40	40
1.4	42	42

Percentage of theoretical capacity

Going back to the motivation of this study the practical capacity in P/hr (at the two entry speeds) is expressed as flow in P/s again and divided by a high speeds of 1.5 or 2.5 m/s ánd by the width of the treadway it becomes the density in P/m^2, see Table 26. This density is the load on the belt in the middle section and is varying from only 0.38 to 1.12 P/m^2. Assuming a body weight of 80 kg this is 30.4 to 89.6 kg/m^2.

In the end recommendations are formulated. In section ② the most assumptions had to be made and the least amount of information is available. At larger widths like 1.4 m the capacity can be higher because three layers can be formed. But there are indications that passengers want to hold on to the handrail and with the AMW in the Paris Metro it is emphasized to hold on during acceleration. With more understanding on the factors of influence here and the possible improvements more benefit can be achieved.
Overall not much is known about the figures on gender, age or luggage and the influence on the capacity. It is clear that it decreases the practical capacity but how much is unknown. Especially at boarding, which is the most difficult part, the impact of impaired or elderly and the presence of luggage is the highest.
If more AMWs are going to be implemented in the future in airports and transfer stations choices have to be made between the types of AMWs. More study is needed to determine which one is the best option in terms of not only capacity but also cost, safety and comfort. Building and testing prototypes is expensive but is crucial in the success of implementing AMWs on a larger scale than currently is the case.