Simulation of the operation of Cable-Propelled Automated People Movers

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Within the field of passenger transport engineering, different systems have been developed for carrying people over short or long distances. One of the general terms is Automated People Mover.

Automated People Movers are driverless transport systems which are used for the transportation of passengers over relatively short distances. The people are transported in closed cabs.

The following figure 1 shows an example of a typical People Mover like the one at the airport in Frankfurt, Germany, used for connecting two terminals.

Figure 1: People Mover at the airport of Frankfurt/ Main, Germany

This example shows the important difference to other passenger transportation systems, as for example buses, since People Movers are used predominantly for short distances, i.e. for distances, that are too long to walk, but too expensive or inappropriate for buses.

For quite some time now, the rope technology industry has also been trying to apply the established and inexpensive technology of using a stationary drive to transport the cab with the help of a rope over a driving disk for People Movers.

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Also the Institut für Fördertechnik (IFT) is now working on the development of such

People Movers. The IFT's previous fields of research are intertwined with this topic in two ways; on the one hand passenger transport engineering is an important subsection of mechanical handling and conveying technology and on the other hand, for over seventy years the IFT has been concerned with intensive research in the field of the rope technology.

There are three manufacturers in Europe well-known for their aerial ropeway technology (Doppelmayr Cable Car (DCC), Leitner, Poma Otis), that has been working on adapting aerial ropeway technology for use with People Movers.

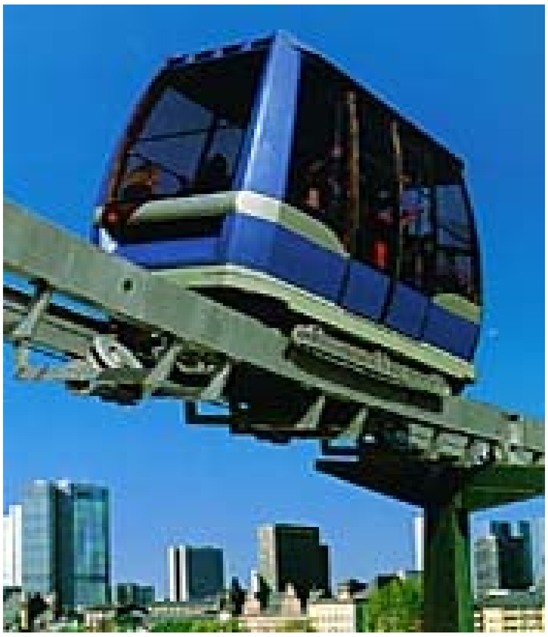

Figure 2a: One of Leitner's People Movers /1/

Figure 2a shows one of Leitner's People Movers. The cabs are fastened by means of clamps to a central propelled rope and drive on a supporting frame (fig. 2b, DCC). For the acceleration or deceleration of the cabs at stations and turning points, rubber tires are used, whereby the clamps of the cabs are opened (fig. 2c, DCC).

Figure 2b: Central rope, DCC /2/

Figure 2c: Rubber tires, DCC /2/

Due to the stationary drive construction described here briefly, Cable-Propelled People Movers are characterised by the fact that all the vehicles in the system, that are in coupled status, are transported with the same constant speed and are accelerated and decelerated at the same rate.

The advantages of the Cable-Propelled Automated People Movers are briefly shown in figure 3.

- Stationary drive
- Mechanics of the vehicles are simple
- Drive control unit is in the stations (not in the vehicle)
- Quiet, because there is no drive and thus no gear unit in the vehicle

Figure 3: Advantages of Cable-Propelled Automated People Movers

In the following main part of the lecture it is not intended to analyse the constructional and system-dependent advantages or the distinctive construction of this system compared to other People Movers on the world market in greater detail. The quintessential point of the lecture will be an analysis of the attainable transport capacity of such systems.

The maximum attainable transport capacity is not only a deciding criterion for the construction and sizing of the system, but also for the planning of the system alignment (incl. number of stations) as well as, first and foremost, the operation of the system. Whereby here, operation stands for the operation strategy.

Out of what has been said so far, it is clear that defining the attainable capacity is a decisive criterion.

According to figure 4, the capacity of a system is influenced by several factors.

Factors influencing capacity

- distance between cabins - driving speed	} =interval	- stopping time in the stations - de-/ accelaration rate
- length of the cabin		- alignment distances

Figure 4: Factors influencing the capacity of Cable-Propelled APM

From publications already available /3/ it is now well-known that the capacity of such Cable-Propelled People Movers can be calculated for a A-B connection with two stations (simplest application form) analytically, i.e. using calculation formula. The figure 5 shows, in the form of nomographs, such an interpretation.

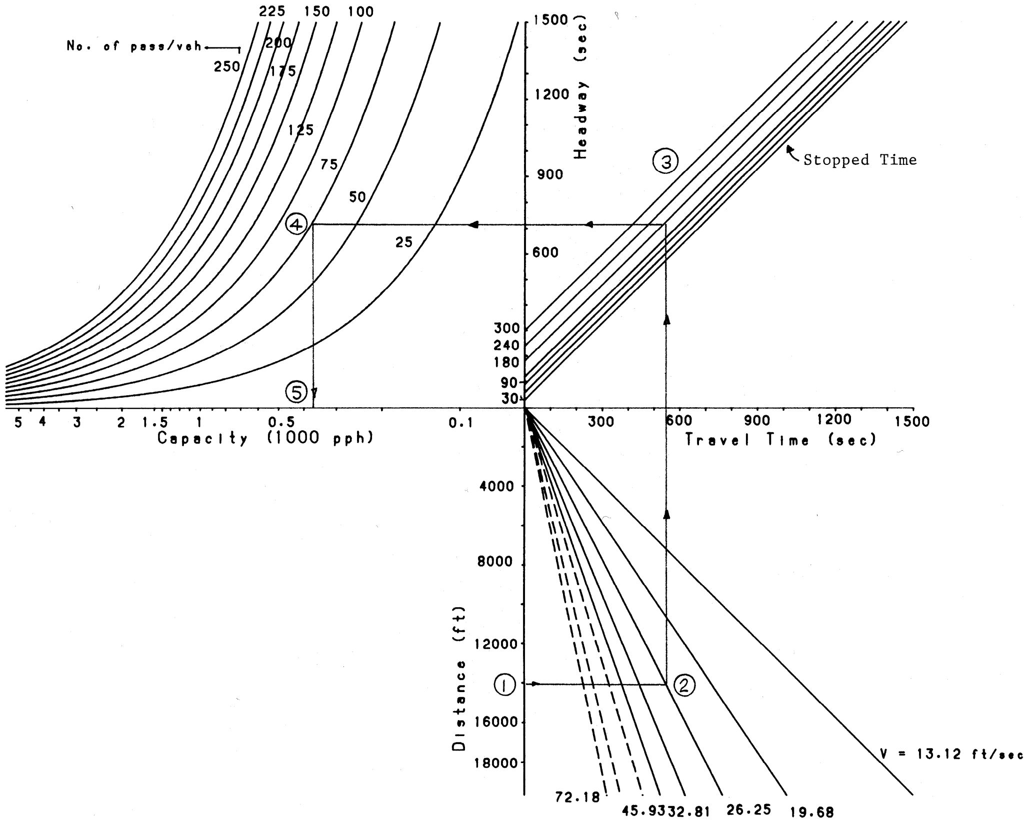

Figure 5: Example for a layout-graph /3/

However, if the capacity of an alignment with n stations is to be calculated, the effort involved in applying the analytic calculation increases disproportionately. For this reason, it is recommended that the operation of such a system be reproduced with the help of a computer simulation. With the help of this tool, the planner can react more quickly and flexibly to alignment modifications, for instance, than when using analytic calculation.

The IFT has been working on this problem with the help of a universal simulation program. This basic program for conveying and handling tasks was adapted to the special problems of Cable-Propelled People Movers by the IFT.

The basis of the simulations carried out by the IFT represents the alignment of a simple A-B relation. A connection between two stations 1000m (0,62 miles) apart from each other was used, resulting in a total route distance of 2000m (1,24 miles). In contrast to conventional capacity calculations, it is now however easy to take further parameters into consideration, for example, the length of the cab changing with its capacity. One result is, for instance, that it is wrong to assume that the total capacity of the system increases to the same degree as the individual capacity of the cabs used (figure 6).

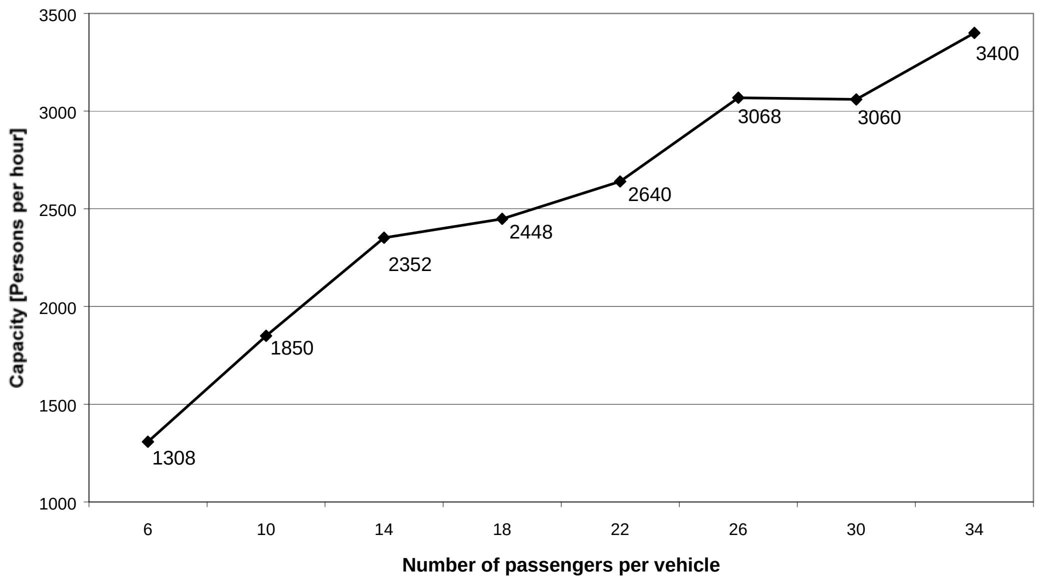

Figure 6: Graph showing system capacity in relation to the cabin capacity

In order to avoid collisions in a Cable-Propelled People Mover system, a certain minimum distance between the cabs must be maintained. With the help of this minimum distance and the length of the individual cabs, the maximum admissible number of cabs on a total system can be calculated. This maximum admissible number of cabs remains constant for a certain interval of the cab length. However, if this interval of the cab length is exceeded, a cab must be removed from the system. As can be seen in figure 6, the removal of one cab cannot be compensated for even if the cab capacity is increased from 26 to 30 persons.

A further substantial factor influencing the system capacity of Cable-Propelled People Movers is the stopping strategy in the stations. With the help of a simulation, the IFT was able to compare three different strategies. (figure 7).

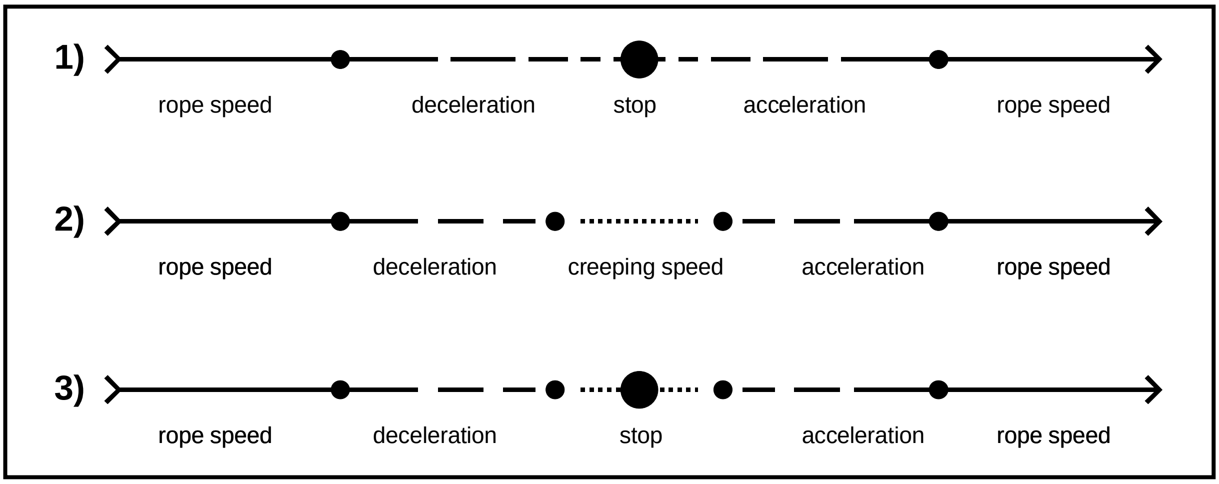

Figure 7: Stopping Strategies

In the first variant, the cab drives into the station, is decelerated and stops. Now the doors open for passengers to unload and load. After the closing of the doors, the cab is again accelerated and then conveyed by the cable once more. In the second variant, the cab is decelerated without actually stopping. It then passes through the stations at such a slow speed (0.3 m/ ; 1 ft/s) that the unloading and loading of passengers is possible. At the end of the unloading and loading zone the doors are closed again and the cab is accelerated to traveling speed. The third variant provides a combination of the first two variants. First the cab drives slowly with opened doors up to the center of the unloading and loading zone, then it stops. After a certain time, it slowly drives up to the end of the unloading and loading zone where it closes the doors. Subsequently, it is accelerated again and clamped to the rope.

Figure 8 shows the attainable system capacities with the different strategies as a function of the applied cab size. It shows that the largest system capacity is attainable if the cab drives through the station slowly without stopping. If the cab stops briefly here, then there is a slight drop in the attainable capacity. The longest headways are needed if the cab only opens its doors after it has stopped, which means that with this stopping strategy the lowest number of passengers can be transported. As already described in figure 6, figure 8 also shows for the other stopping strategies that an increase in cab capacity by increasing the length of the cabs does not necessarily lead to an increase in the overall capacity of the system.

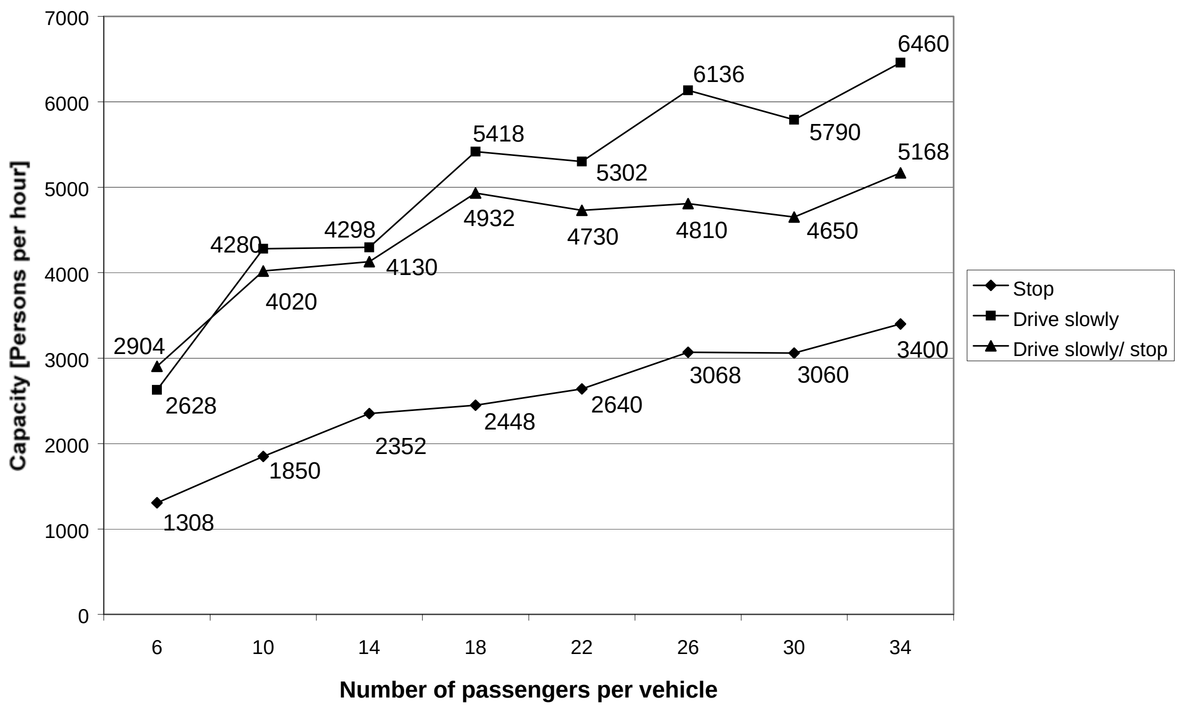

Abbildung 8: Attainable system capacities with different strategies as a function of the applied cab size

The results of our simulation presented up to now could also have been determined with some effort by analytic calculation. However they only show the operation of a People Mover system under ideal conditions. In real life, the situation would differ greatly. In daily use, delays occur through irregularities during operation and these endanger the miniumum distance which must be maintained between the cabs if collisions are to be avoided.

Even if the operation of the system is technically perfect, these irregularities occurr, as for example from delays in unloading and loading passengers if at the point in time intended for closing the doors a passenger is still standing in the light barrier.

If such irregularities occur repeatedly, the system can be subjected to an emergency stop as the distance between two cabs decreases to such an extent that a collision would otherwise be inevitable. Such stochastically scattered irregularities cannot be taken into account when analysing an entire system by means of a conventional calculation. This means that the real operation of a People Mover system can only be analysed with the help of a simulation program.

In order to ensure the failure-free operation of a People Mover, it is essential to use a simulation during the planning phase to evaluate what influence irregularities have on the overall operation.

The influence of such irregularities on different People Mover system concepts has been simulated at the IFT. In order to ensure a true comparison, all the systems compared were given the same alignment and the same number of stations. Only the stopping strategy in the stations was varied. The following four types of stations were considered: Stations where the cabs

1. stop,
2. pass through slowly,
3. pass through slowly, but include a brief stop in the center and
4. exit on an off-line guideway.

Figure 9 shows the alignment on which the simulation is based. It is composed of 6 sections, each 350 m long, with a total length of 2100 m.

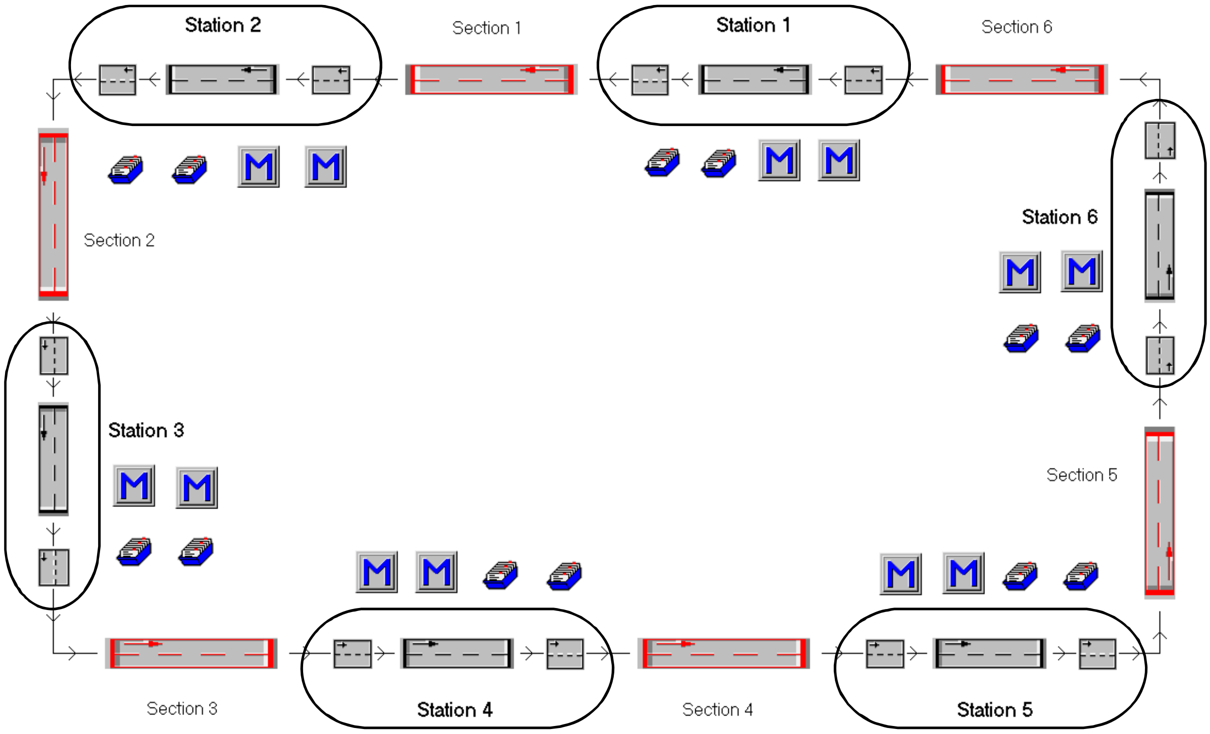

Figure 9: Alignment used for the simulation

For the simulation it was assumed that at each 10th stop of a cab in the station an irregularity occurred. The temporary delay of the cab's departure due to irregularity was spread out evenly between 0 - 2.5 sec. For each station, the irregularities were produced individually and independently of other stations by a random generator.

The operating time of the system until an emergency stop occurs depends on the difference between the actual and the minimum admissible interval. An emergency stop is inevitable if the distance between two cabs falls below the necessary minimum.

As all four simulations are based on the same nominal capacity (3000 passengers per hour) buffer times have been included which vary according to the maximum capacity attainable with a certain stopping strategy. The system concept which has already reached its maximum transport capacity of 3000 persons an hour on this alignment due to its loading and unloading strategy (stopping in the station) has the least leeway.

As the result of each simulation run varies due to the coincidental distribution of irregularities occurring, it is necessary to carry out a number of individual simulations. In the worst case, the emergency stop had to be initiated after less than half an hour of operation time. With another concept, this was only necessary after a few hours. (NOTE: Detailed results will be shown during the lecture.)

Conclusion

Purely analytical calculations based on found capacity lead to non-practical results as irregularities in the stopping time of the cabs in the stations cannot be taken into consideration. Depending on the system, these can however lead to more or less early emergency stops of the total system. Therefore, in order to ensure troublefree and economical operation with an optimized layout, it is essential to use a simulation when planning a system.

In addition, the simulation provides a simple method of checking at an early planning stage just how efficient conceptional modifications to a People Mover system are going to be.

Outlook

For the operation of a People Mover system, it would be a great advantage if a new control system could be developed which could compensate for the reduced distance between two cabs (due to extended stopping time in a station) by a non-standard shortening or extension of the stopping time so that troublefree operation is ensured. The "blockage" would have to be diminished in direction of transport from the last cab on that has a shorter than nominal distance to the one in front..

A further possibility for evening out irregularities would be to introduce a compensation section on which the cab would be transported with opened clamps over a rubber wheel drive at a speed greater or lower than the nominal traveling speed. By decelerating or accelerating a cab the distance between the cabs would thus be corrected.

References

/1/ Leitner, People Mover Information Brochure

/2/ Doppelmayr, DCC People Mover Information Brochure

/3/ Neumann, E. S.: „Planners guide to Cable-Propelled People Mover Systems for urban activity centers“, Mid-Atlantic Universities Transportation Center, 1990