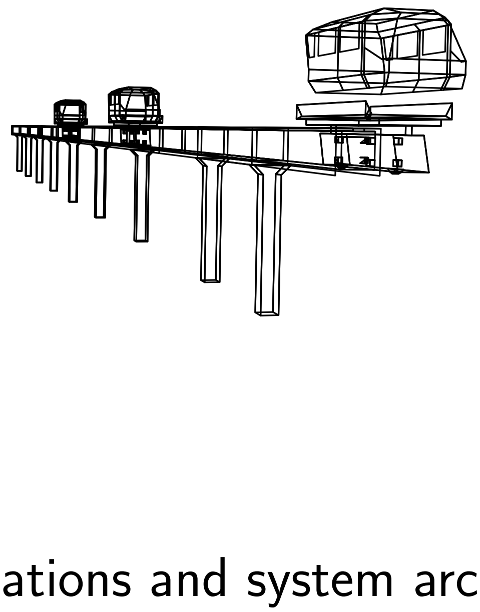
Modular Automated Individual Transport

MAIT



General specifications and system architecture [1]

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Preface

Modular Automated Individual Transport (MAIT) is a new approach to person and light freight ground transportation [1], designed with the following *objectives*:

- increase in quality of life
- socially acceptable
- environmentally friendly
- economically viable
- aesthetically pleasing

The consequent derivation of the MAIT architecture from these objectives is the core of this document.

Motivation and purpose of this document

MAIT is a highly complex *multi-modal* and *technology integrating* transportation system (*TS*). A proper structure, an appropriate distribution of data and functions, common operating principles, standardized interfaces and quality measures are *necessary to ensure a reliable and safe functioning*. It is further desirable to divide the entire system in smaller parts which can be developed and tested separately. Therefore, this document has the following purpose:

- definition of *global specifications*: These are meant to be the starting point of a top down system design that is logically derived from the above mentioned main objectives.
- generation of *local specifications* from global specifications (see Fig 1): Local specifications allow the development of MAIT compliant system hard and software. Local specifications allow also the independent development and test of system hard and software.
- *knowledge integration:* since MAIT is an entirely new concept, it has little technical or scientific bases in any traditional faculties. As MAIT is an interdisciplinary project there is the need to integrate the knowledge of specialists with various backgrounds.

The top-down system design procedure goes as follows (see also Fig. 1):

1. definition of general transport system specifications from objectives.
2. derivation of system architecture from general specifications.

3. identification and definition of system structure and processes.
4. Quantitative definition of properties, interfaces and quality criteria (local specifications).

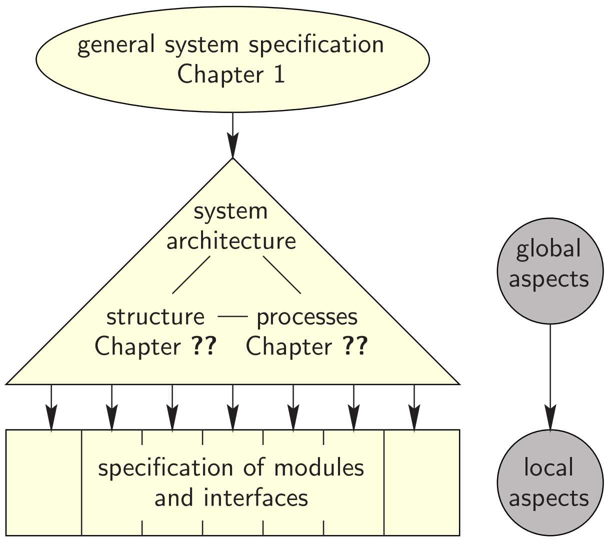

Figure 1: Top down system design approach.

Target audience and document organization

This document is targeted primarily to *MAIT system developers* which includes everybody who would like to contribute with their knowledge to the development of MAIT .

As introductory literature we recommend the MAIT introductory or concept paper [2, 1]. Chapter 1, is of general interest and written with few technical terminology. The general specifications serve as guideline for all following chapters, which are of technical nature.

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The *system architecture* is split in two chapters: the *global structure* of MAIT is described in Chapter **??** and the *operating principles and global processes* are explained in Chapter **??**.

The remaining chapters of this documents describe the functions of modules, sub-systems and their interfaces in more detail, refining and quantifying the structures of Chapter **??** and processes of Chapter **??**. An overview is shown in Fig. 1. Note that the MAIT development covers a large spectrum of disciplines and not all sections may be interesting for everybody.

Contents

Chapter 1

General specifications

In this chapter the intended Transportation System (*TS*) is outlined, its characteristics are identified and the *general specifications* are derived. These general specifications serve as guidelines for all following chapters. As a first step we derive in Section 1.1 some general system characteristics from the *objectives*:

- increase in quality of life
- socially acceptable
- environmentally friendly
- economically viable
- aesthetically pleasing

In Section 1.2, marketing strategies are discussed and more detailed system design relevant aspects are extracted. Based on the results of these first two sections, the rest of Chapter 1 describes the TS itself. First we address characteristics that apply to the TS as a whole and define:

- a general design philosophy (Section 1.3) and
- safety, comfort and security criteria (Section 1.4).

Then the different parts of the system are organized by:

- infrastructure (Section 1.6)
- vehicles (Section 1.5)
- operation (Section 1.7)

1.1 General characteristics

The translation of the design objectives (see above) into *general characteristics* is considered "common sense". It is a collection of opinions from different people that are supposed to know the potentials of state of the art technology. Note that these are the characteristics primarily from the user's point of view. More detailed aspects that are important for developer, producers and operators are addressed in Sections 1.2.

1.1.1 Increase in life quality

Here, only those aspects of life quality are considered that are directly related with transportation. Other aspects are discussed in Sections 1.1.2 and 1.1.3. Concerning transportation, it is understood that people will perceive an increase in life quality if their latent demand for mobility and flexibility can be satisfied. Therefore, the important characteristics of the new TS should be:

- *door-to-door transport*, without intermediate transfers
- *individual vehicles*, people should have the possibility to reach their destination individually, or with persons of their choice
- *on-demand availability*. Vehicles should be available on-demand and *24h a day*
- *short trip times*, especially for medium and long distances. This means no congestion and high traveling speeds for long distances
- *high ride comfort:* people should be able to work, sleep or eat during the trip
- *transport flexibility*. It should be possible to transport different items like shopping trolleys, pushchairs, skis, bikes or smaller furniture. It would further desirable to be able to do some "useful" activities during the trip, like reading, working with a computer etc
- *easy and consistant to use*

For professional users, (mainly freight transport) the following (additional) points are of importance:

- *reliability:* vehicles should always arrive in time
- *integration of in-door and out-door transportation*, in wharehouses and to production machines
- *transport services:* a flexible transport system should offer services, supporting trends in manufacturing that prove to increase productivity and efficiency as for example *just-in-time delivery* and decentralized production (*out-sourcing*, *modular sourcing*, *down-sizing*)

1.1.2 Social aspects

- *High safety* for users and non-users: the system should be safer than present car and public transport in order to reduce injuries and avoid casualties. This would help to increase public health.
- *Low pollution:* the system should have low, if possible no emissions while keeping noise levels at a minimum.
- *Available for everybody:* for people off all ages and abilities.
- *Affordable for everybody:* for people of all social groups.

- *Low land use:* cities and countryside should be for the people to live in and not for transport.
- *Stress free travel:* would further contribute to a healthier live. Passengers should feel in control of their destination and have a smooth and comfortable ride.
- *Family trips* should be possible, assuming vehicles large enough for four adult persons plus space for baggage.
- *Arrangement of seats:* persons should be seated such that they can easily communicate during travel.

1.1.3 Environmental aspects

The TS should be low in consuming natural resources and polluting the environment. This means:

- low energy consumption
- low consumption of materials
- low emission of toxic matter
- low noise
- low interaction with nature and wild-life
- low land use

All items apply to the entire life cycle of the system and components, comprising production, operation and recycling/disposal.

1.1.4 Aesthetic aspects

All visible parts of the TS (mainly guideways, rails and stations) should be aesthetically appealing and they should compliment the architecture of the city and be unobtrusive in the countryside.

1.1.5 Economical viability

The system should be economically attractive for system users, service providers, operators, and manufacturers. More details are developed in Section 1.2.

1.1.6 Other aspects

- *Compatibility with other transportation systems:* on the one hand the new TS need to provide a certain compatibility or option for cooperation with the present TS, in order to allow a *co-existence* and a smooth transition. On the other hand the new TS must be a useful complement to the entire transportation infrastructure (both passenger and freight transport) *after its implementation*.
- *Fun:* the introduction of the new TS will be a lot easier if people just like to ride it.

1.1.7 Preliminary conclusions

A TS that must be available1 24 hours a day, easy to use by almost everybody and at the same time efficient, flexible, economic, environmental friendly, safe and reliable. This can only be accomplished by a complete *automation of the transport system* . However, it needs to be shown that such a system can be efficiently solved with today's technology.

Vehicles need to be as small and light as possible in order to reduce space, costs, visual impact and to increase flexibility of infrastructure. A vehicle sharing option would further minimize land-use and pollution. For *freight that is too large or too heavy to be transported in one or more smaller vehicles*, there would be the following options:

- Transport with conventional rail, ships or trucks (as special transport). Industry that is dealing with large or heavy products has usually access to one of those transportation means.

- Transport with an automated transport system that has a separated network for heavy freight. This network should also be compatible with the small vehicle size network.

Electric moters can provide high energy efficiency, low emission and low noise, but the flexibility of *electrically driven vehicles* is limited by the inherent storage problem of electrical energy. The tracks should be small, inexpensive, flexible and with low visual impact. Of special interest are *elevated guideways* that can help to remove high density through traffic from ground level. This may also help to facilitate a transient from present transport systems to the new TS as it separates the new TS from car traffic and pedestrians. However, it is not expected that elevated guideway structures can provided everywhere door-to-door service. They may also be aesthetically unacceptable in historic city centers with narrow streets.

It appears that there is no single technological solution that sufficiently satisfies all criteria. Therefore, the new TS need to consider *solutions that integrate different transportation technologies*.

1.2 Economical design constraints

The new TS needs to be economically attractive if it is to be realised, preferrably from an early stage of the start-up phase if it has any chance of being realized. It is therefore important to include marketing concepts in the early development phase.

A transport network is a *critical mass system*, meaning the usefulness for the system user (or consumer) depends on the *number of users*. Once a critical amount of system users (critical mass) is exceeded, the system becomes so attractive that more and more users want to profit of it and the system can expand until market saturation is reached. The business of critical mass systems is complex since it requires the agreement of many *market participants*, not only of users but also of manufacturer, component provider, infrastructure provider, service provider etc [3]. Each of these participants will compare the possibilities and challenges of the new TS with existing alternatives (comparative advantages) and most likely each participant will do it independently. This means none of the participants will make sacrifices for a desirable common goal that might become real at some time in the future. Instead, their decision to adopt a new system will be based on the advantages that they *perceive*. These *perceived advantages can be significantly different from rational, objective or technological advantages that often prevail in the system developer's eye.*

In this section, we want to highlight only the most important marketing aspect and their design relevant aspects. However, design and project management is often interdependent. This section is organized as follows: First the aims are defined and general strategies are proposed and evaluated. Then all adoption factors are analyzed (Section 1.2.2). Finally we characterize different market participants that potentially profit from a new transportation system, analyze their perceived advantages and extract system design relevant decisions.

1.2.1 Aims and strategies

Marketing literature suggests in general the following procedure: (1) to analyze the market, (2) to define aims based on market demand, (3) to deduct strategies from these aims and finally (4) to develop the system according to those strategies. However, the question is:

how can the user (market) want something that does not exist ?

The users desires will usually remain within the limits of what he thinks is realizable. The user is not always informed about alternatives. Therefore, the general characteristics in Section 1.1 of the new TS have been defined by people who know the technological alternatives. Thus, the *the aim is:*

the development and implementation of a transportation system with the characteristics described in Section 1.1.

There are *two principally different strategies* on how to achieve this aim where both strategies have a strong influence on the system design:

1. *morphogenetical strategy:* The new TS is achieved by a gradual transformation of the present transportation system

2. *substitutional strategy:* The new TS is built up in parallel to the present system and replaces it gradually as it expands

1.2.1.1 The morphogenetical strategy

Elements of the morphogenetical strategy are:

- improvement of navigation and automation of cars and trucks
- reduction of energy consumption and gas emission of cars, trucks, trains, ships and airplanes
- automation of heavy and light rail trains, in general Automated People Mover (APM) technology.
- development of high speed trains
- improvement of multi modal transport. This includes:
  - cars that can be loaded onto high speed trains
  - cars that can run on roads and rails (dual-mode vehicles)

  - information systems that allow the organization of a complete trip using multiple means of transport

The main *advantages* of the morphogenetical strategy is the ability to evolve smoothly from present systems:

- present infrastructure can be used
- industry can continue improving the products that they already manufacture
- the users do not need to change radically their behavior
- judicial framework, public and political decision making procedures are well established

The main *disadvantages* are:

- the compulsory downwards compatibility to present technologies limits the problem solving potential. It is likely that the TS as outlined in Section 1.1 can never be achieved and a substitutional strategy is inevitable at a later time
- the user perceives predominantly the additional costs (for automation, navigation, infrastructure) but too few immediate profits. For this reason changes can be delayed

1.2.1.2 The substitutional strategy

the substitutional strategy is characterized by:

- new vehicle technology that requires a new type of infrastructure. One example is Personal Rapid Transit (PRT) systems [4, 5]
- its introduction has more the character of a revolution rather than that of an evolution

The main *advantages* are:

- system design can fully exploit state of the are technology and the characteristics outlined in Section 1.1 can actually be achieved. As a consequence, people who use it would immediately perceive the differences
- the new TS can be designed with more homogeneous operating principles compared with a combination of improved conventional TSs. This would result in an easier operation, higher efficiency, higher safety and reliability

The main *disadvantage* of the substitutional strategy is that present TSs, technology and infrastructure cannot by used to the degree as it is the case for the morphogenetical strategy. The new infrastructure must be installed in addition to the existing one and they may interfere with each other. In the further design process *we will follow the substitutional strategy* because:

- the priority is to achieve exactly the TS as outlined in Section 1.1 and not a sub-optimum approximation
- the transition problems are solvable by an appropriate system design and project management. The following options should be considered:

- use of elevated guideways for the main traffic streams in order to minimize the interference with present infrastructure
- use of present infrastructure (bus-lanes, metros-lines, trams, bridges, tunnels, public car parks, etc)
- reduction of in-town public car-parks

1.2.2 General adoption process of the new TS

Here we discuss in general all relevant factors that persuade a market participant to adopt the new TS. Ideally, each *adopter* passes successively through the following stages:

1. awareness stage
2. interest stage
3. evaluation stage
4. trial stage
5. adoption stage

It is important for the project management, to provide each adopter at each stage with the right information. In order to measure the degree of *adoption* the following quantities may be considered:

- *vehicle km per year.* This measures the usage of the TS i.e. how many passenger*km* or freight km have been transported with this system
- *number of households or businesses with access* to the new TS

Vehicle *km* per year is more appropriate since it reflects not only a measure of the number of people who use the TS but quantify also the *intensity* with which the system is used. An upper limit (market saturation) would be all passenger + freight *km*s per year that are performed by today's TSs. The following factors need to be considered in order to accelerate the adoption process:

1.2.2.1 performance specific factors

- *Relative perceived advantages:* each market participant will individually perceive certain advantages of the new TS, relative to present alternatives. It is important to *communicate real existing advantages* to each of the market participants.
- *Compatibility to existing infrastructure:* How easy can the new TS be integrated into the existing transport infrastructure? Important issues are:
  - technical compatibility
  - changes in organizations (companies, politics, private)
  - changes in personal behavior and habits
  - changes in legislation, insurance and safety standards

- *complexity:* should the new TS be a lot more complex than present systems then participants will hesitate to adopt the system because:
  - the user is confused, because it is too difficult to use it
  - it becomes too expensive to develop, just because of the number of different devices that need to be designed
  - it becomes risky and expensive to manufacture and operate because new methods need to be developed
  - expensive specialists are required to develop and operate the system reliably and safe
- *upgradability:* especially when investments are high, developers, manufacturers and operators are more likely to adopt an upgradable system because it will guarantee support and operation in the far future
- *triability* if the TS (or parts of it) can be tried before manufacturing, operating or usage then the adoption risks can be lowered and doubts removed
- *observability* is the capability to communicate the real advantages of the new TS to the market participants. Communication channels that exist for present TS (TV and radio, journals, consultants, lobbyists, conferences) may be inexistent for the new TS

Since we have decided for the substitutional strategy (see Section 1.2.1), the weak points of the new TS are compatibility, complexity, triability and most likely also observability. The system design must pay particular attention to the factors relative perceived advantages, compatibility, upgradability, complexity and triability. The project management needs to work mainly on triability and observability.

1.2.2.2 adopter specific properties

- Properties of individuals (users, decision makers in companies or organizations, etc) such as age, income, education, status, etc.
- Properties of companies and organizations as a whole such as size, company culture, type of employees, etc.

1.2.2.3 external factors

- *Political, judicial environment:* these are market regulations and restrictions, safety regulations, patent law, political decision making etc.
- *Social factors:* awareness of environmental problems, acceptance of technical innovation, social status, user and interest groups, quality of education.
- *Economic situation:* state of economy, marketing structures, culture of companies, financing, etc
- *Technical environment:* standardization, technological state of the art.

The external factors concern predominantly the project management. In the remaining part of this section we want to focus on the analysis of the relative perceived advantages along with adopter specific properties in order to extract more detailed system design criteria. For this purpose, the adopters have been divided into the (interest) groups:

- users
- operators
- manufacturers and developers

1.2.3 User specific properties and relative advantages

Here we characterize different *user* types and high-light reasons why they would use a TS (or why not). It is obviously a characterization of stereotypes.

1.2.3.1 Type 1: The irrational car buyer

This is the type of man who buys his car predominantly for one or several irrational reasons:

1a *the traditional irrational car buyer:*
"I always bought the car of brand X and I have always been satisfied"

1b *the status symbol irrational car buyer:*
" How will they look at me if I do not by the car of brand X or Y"

1c *the emotional irrational car buyer:*
"This car looks really cool, I have to get it"

1d *the socializing irrational car buyer:*
"My friend X, is really a cool guy and he also has this car"

1e *the spontaneous irrational car buyer:*
" I urgently need to buy a new car so... just give me this one!"

The typical irrational car buyer drives to work by car. He parks it in a garage or in front of his house or apartment. His residence is usually in more scarcely populated suburban areas. He has experience with traffic congestion but either he accept it as the most normal thing of life or, if the traffic situation becomes serious, he has no problems in taking a 20km longer route in order to avoid stop and go traffic. The car is an integral part of their private live that must always be near. The car has more a status of a pet or a religious symbol rather that of an object. Driving the car and the sound of its motor is enjoyable and gives a subjective feeling of being in power of something, to be free and independent.

This user type is probably the most difficult to convince of a new transportation system. He will perceive any transport that want to compete with his car as a threat. He is not interested in analyzing traffic problems objectively. His suggestion for improving the traffic situation is to extend the road network.

The traditional and status symbol irrational car buyer are the most pathological cases, it is the user type that resists most adopting a new TS.

The socializing irrational car buyer will also hesitate to accept a new transportation system, but as soon as others accept it, he will follow. He can be considered as an *amplifying factor after the system reached the critical mass*.

The *emotional and spontaneous irrational car buyer may be easier to convince of a better transportation system*, if communicated in the right way. The emotional irrational car buyer is also the prime target group of the car industry's publicity campaigns.

It is estimated that user type 1 represents a large share of all users. It is therefore important to recognize their fears, otherwise they will block the expansion of the system before it reaches its critical mass.

The design relevant aspects are:

- *characteristics of the new TS should be similar to the one of a car*. The new vehicles should not appear as something completely different, but something confident with more intelligence inside Maybe the name "INTELLICAR" would be the most appropriate. In particular the following elements are important:
  - access: spontaneous, any time, the way to open it should also be car-alike
  - operation: user should remain in power of changing directions at any time
  - ownership: users should have the possibility to buy their own vehicle
- *putting a high importance to the design aspects of user types 3 and 4*. The irrational car buyer could be addressed indirectly by those groups

1.2.3.2 Type 2: The rational car buyer

This is the type of user who buys his car predominantly for one or several rational reasons:

2a *the minimalist rational car buyer:* He will search and buy the cheapest available car that will bring him from place A to place B

2b *the optimalist rational car buyer:* He will read all available auto journals and car test-reports in order to find the car for his personal needs

2c *the universalist rational car buyer:* Is similar to the optimalist rational car buyer, but reads also journals of general interest. Therefore, his decision which car to buy is also influenced by factors that are not car specific, as for example environmental, political, economical etc

For this user type the car is no more than an object that has to provide certain functions. He uses his car when he needs it and if he gets stuck in a traffic jam or the car breaks down he hates it. The rational car buyer is not only a more critical person, he is also willed to make efforts in order to get the appropriate information. When confronted with a new TS, this user type is likely to adopt it if the advantages fulfill their expectation. He will analyze home-to-work trip time and costs. First he will compute the costs with the assumption that he keeps his car.

- If the costs for using the new TS are higher than using the car, he will verify if he could do all his transportation needs without a car.
  - If he cannot do everything without a car he will not use the new TS but continue to drive the car.

  - If he could do everything without a car and if the costs are still higher than the car-only option then he will not use the new TS but continue to drive the car.
  - If he can do everything without a car and if the costs are lower than the car-only option then he will sell his car and use the new TS exclusively.

- If the costs for using the new TS are lower than using the car, he will use the new TS while keeping the car. If he has a second car and realizes that he is no longer using it he will sell it. Eventually he would also sell his first car when owning it is no longer justified.

Since the network of any new TS is incomplete (car is still necessary), the only way to attract this user type is to offer transport that costs no more than the operating costs of their car (essentially petrol, tax, insurance). The universalist rational car buyer will maybe recognize that the new TS can increase his own and other people's quality of life and will therefore be ready to pay a slightly higher price than the operating costs of his car. The universalist rational buyer will also appreciate being able to work during the trip. Universalist rational buyers often have a higher social status and are considered as *opinion multipliers* because others are imitating their behavior in order to achieve a higher status or to appear as if they had achieved a higher status.

Universalist rational buyers are therefore of importance during the start-up phase, before the critical mass is reached. Rational car buyers are less numerous than irrational car buyers, but they will immediately use the newly implemented system if it is advantageous for them (see above discussion). The design relevant aspects are:

- the costs of the new TS must be equal or below the operating costs of a car
- equivalent or shorter door-to-door trip times than car or public transport
- additional functionality or services will increase the usage within this type of users:
  - working during traveling, Internet connection
  - possibility to sleep conveniently for long distance or over-night journey
  - possibility to take care of children during the trip
- when user type 2 is a parent they can be influenced by user type 4, (see design aspects user type 4)

The first two items concern also project management and network design.

1.2.3.3 Type 3: The person in the household without car

To date, many family households still own a single car. In most of these cases, the person with car (usually male of user type 1 or 2) drives to work and the other adult person (usually female partner) remains without a car during the day. The person without a car is then largely dependent on public transport, which she needs for the following purposes:

- for the trip to work
- for shopping, eventually with children or baby
- for visiting friends and other events

The person without car is a very important pre-critical mass opinion multiplier as she has an influence on user type 1 and 2. She will prefer the new TS to public transport if it offers a better service at a similar price. Therefore, the design aspects are:

- easy to operate:
  - a prepayed card serves as ticket and as a key to open a vehicle
  - simple destination selection
- personal and secure: no other (undesired) people travel in the same vehicle. No direct contact to other people in crowded places.
- easy to load: baby carriages or shopping charts can be rolled into the vehicle
- convenience: quiet, comfortable and smooth travel, possibility of taking care of children during the trip
- influence by user minors, (see design aspects user type 4)

1.2.3.4 Type 4: minors

Minors, up to the age when they are allowed to get a driver's license, are dependent on bicycles, parents and public transport. The main transport tasks are trips to school, friends and various events. Boys in general could become enthusiastic about futuristic and high speed looking vehicles that move silently along some fancy guideways. Most girls may be more attracted by a clean inner vehicle, round and refined shapes of furniture with warm and soft colors. Girls are often afraid of traveling with strangers and hate crowded places, where direct contact with unknowns is inevitable. For further analyzis we consider two sub groups of minors:

4a *minors less than 12 years old:* Parents will usually decide about the mean of transportation is used by their younger children. Therefore, in order to attract minors of age below 12 the parents need to be convinced that the new TS has advantages over other alternatives. The important factors are:

- children can do certain trips alone (school)
- children are safe and secure when they are traveling alone
- the new TS is not a danger for children on the streets
- the kids should love to travel with the new TS as it transmits also some joy to their parents

4b *minors of age between 13 and 18:* This group will play a central role during the pre-critical mass period, but also in the long term success of the new TS. The reason is:

- there is an increasing demand for transportation:
  - social activities increase (visits of discos, events, bars, friends, etc)
  - secondary school, college or university are usually more remote from the parent's home than primary school or kinder garden. As a consequence also friends and other activities are located more widespread

At present this demand is insufficiently satisfied by public transport, in particular in rural areas, during night hours and weekends. Also many parents are reluctant to drive their children to wherever and whenever they want. Therefore, there is a potential that can be satisfied by the new TS.

- during the age from 13 to 18 opinions are forming and stabilizing. If this group of users adopt the new TS it would represent the first generation that no longer considers the private car as the transport of choice
- Young people wil have a strong influence on user type 1, 2, 3 and 7

The design relevant aspects are:

- parents should have the possibility to send children alone to school, entertainments (where the older ones may drink alcohol) or visiting friends and relations
- the new TS should not endanger children playing in the street
- vehicles should be protected against persons who intend to break in violently
- the control system of the TS as a whole should be securely protected against malicious diversion of vehicles (ie by hackers)
- the outside appearance of the vehicle, guideway, panels bottoms and displays should look elegant and well designed. Maybe the vehicle sounds (rolling, gliding, door-opening) should be similar to those in SCIFI movies
- the inner architecture should be warm and welcoming, the furniture should be of round and refined shapes with soft colors
- all buttons and displays should be placed in a way that small children can operate the vehicle and read all relevant messages
- already in an early stage, the TS network should include centers like discos, cinemas, bars, etc

1.2.3.5 Type 5: The elderly

Elderly people are a substantial and ever increasing part of western society as live time expectancy increases. In addition, many elderly people live alone because their children and relatives live further away than in the past. They need to manage their lives and transportation without demanding support from the younger generation. Many of them will be physically weak, visually or acoustically impaired, or have lost the ability to drive a car. Transport is usually needed for:

- shopping
- visiting relatives, friends or other events

Even the novel TS would be of great benefit to elderly people they may be slow to adopt it because of difficulties in changing habits and fear of new technology. Therefore, the design relevant aspects should be:

- traveling should not be physically demanding

- it should be simple to operate and similar to existing transport
- the way it is used should be consistant, for example in the position of button, displays, language of instructions and messages etc. Elderly people need to be confident that they can control their travels wherever they go
- travel in wheel chair should be unrestricted
- operation should be possible also for blind and deaf

1.2.3.6 Type 6: impaired persons

Persons who are physically, visually or acoustically impaired can be expected to eager to adopt the new TS, as outlined in Section 1.1, if they are able to use and operate it without difficulties. The design aspects overlap largely with those of user type 5. In addition, certain facilities for the disabled are standardized.

1.2.3.7 Type 7: other public transport users

These are people who use exclusively public transport *and* who do not belong to user types 3, 4, 5 and 6. They may use public transport for one of the following reasons:

7a they cannot afford to buy and maintain a car (even though they would like to)

7b they don't like driving a car or have not obtained a drivering license

7c they hate cars and driving. They may be environmentally sensitive and believe that public transport is positive for the environment and society. Others are nostalgic about trains

Types 7a and 7b would instantly adopt the new TS if they get a better service at similar or lower costs compared with present public transport. Type 7c would adopt a new TS once they are convinced that it is socially acceptable and environmentally friendly.

1.2.3.8 Type 8: professional users

These are usually companies or organizations that use transportation for

- Freight transport: within buildings or between remote production sites.
- Personal transport: to move people between buildings, inside or between remote production sites.

The professional users are of particular interest for a first commercial application of the new TS because:

- they will verify objectively if the new TS has a better performance and adopt it if the costs justify the additional value
- companies and organizations will become opinion multipliers when their employees who are type 1, 2, 3 and 7 users experience the new TS at work
- freight transport is particularly suited for testing the safety of the new TS

The design relevant aspects are:

- efficient freight transport, including:
  - easy handling of the transported freight
  - efficient logistics, with the option of integrating the new TS into the companies material handling systems
  - option for automated loading and unloading of vehicles
- integration of in-door and out-door transport. This would reduce costs for handling and intermediate storage. Ideally the transportation should be all the way from good-in, to production machines, and on to wharehouse and the customer
- integration of passenger and freight transport. This would save costs compared with the operation of two separate systems
- option for customized vehicles for special purposes, such as:
  - transport of hot and cold goods
  - vehicles with special furniture, equipment or tools

1.2.3.9 Diffusion strategies

The schematic qualitative diffusion diagram in Fig. 1.1 shows which user type is adopting the new TS and at what time. It shows the strength of the influence (thickness of arrows) between the different user groups. These influences can be reinforced by appropriate marketing strategies and communication. There are different dynamics for the pre- and post-critical mass period: the post-critical mass period is characterized by general self-amplification of the diffusion within and between all user types. Concerning the system design, it is important to focus in the start-up on the design aspects for user types 8, 3, and 4. In addition, the system should be flexible enough to accommodate the design criteria of all other users at a later stage.

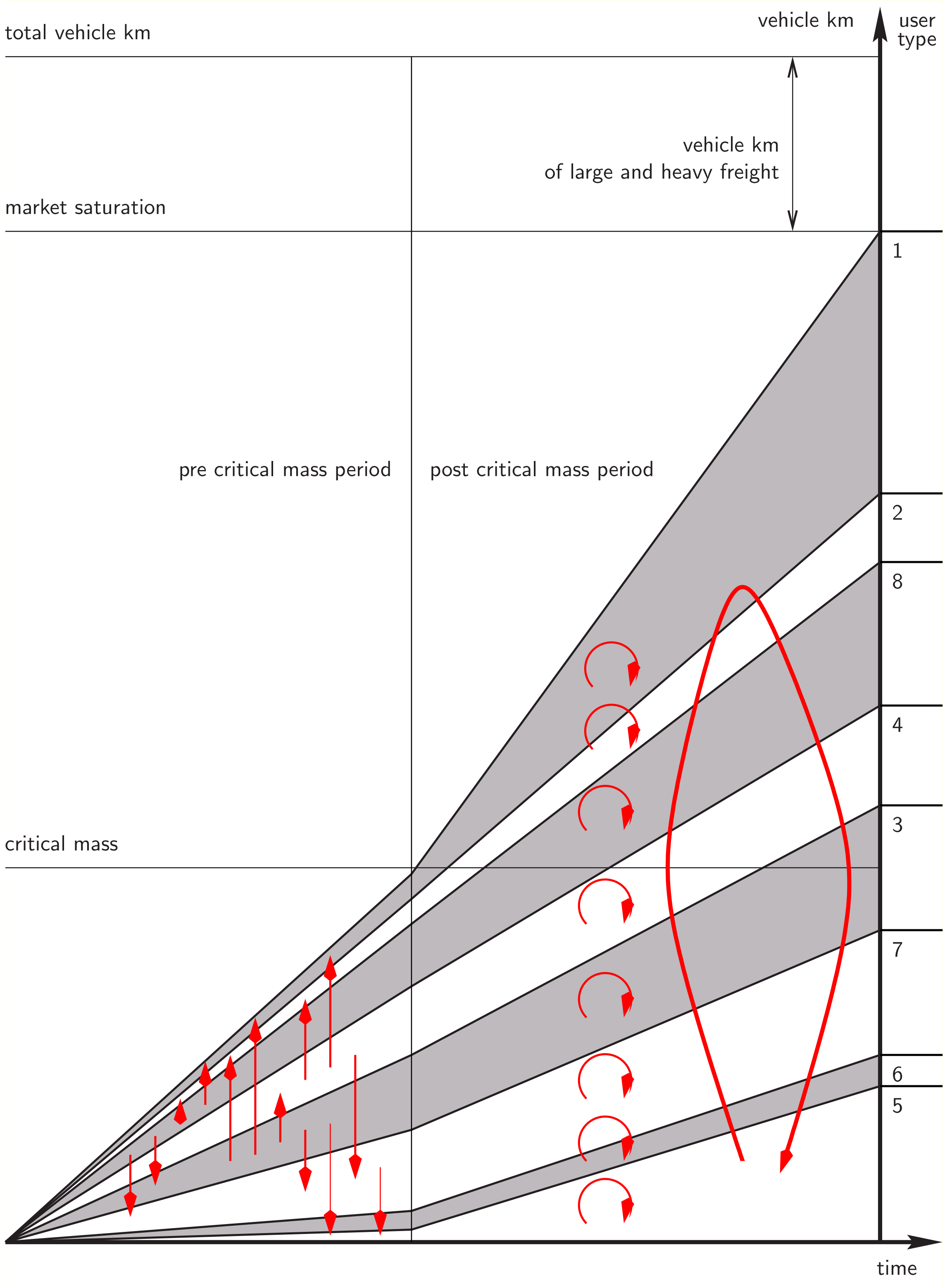

Figure 1.1: Schematic diffusion diagram and influences between user types

1.2.4 Operator specific properties and relative advantages

By *operators* we mean all companies, institutions, organizations or individuals who buy or rent parts of the TS and offer various transport services to users or other operators. Common objectives of operators are

- low fixed costs (investments)
- low operating and maintenance (*O&M*) costs
- high revenue from the services they provide

Fixed costs, operating costs and revenue vary strongly, depending on the type of operator. In the following we analyze different types of operators, whereby one single company, institution or organization could provide some combination of services.

1.2.4.1 network providers

own or rent the transport infrastructure and make it available to the vehicles of the transport providers.

- *Fixed costs:* infrastructure.
- *O&M costs:*
  - energy
  - labor for control center infrastructure maintenance and security.
  - repairs and maintenance
- *revenues:* charging transport providers for infrastructure use

The fixed costs of infrastructure providers represent the main capital of the TS. In addition the initial network needs to be of a certain minimum size, to be useful. Design aspects are:

- low infrastructure costs: low guideway costs per km, use of existing infrastructure
- high reliability
- compatibility with other modes of transport
- reliable technical support
- upgradability by future technologies

Before investing major capital in a technological new TS the network provider must be sure that:

- the planned network will provide the expected performance
- the system usage is sufficiently high

1.2.4.2 transport provider

; usually own a vehicle fleet.They use the infrastructure and offer transportation services to the service providers.

- *Fixed costs:* vehicle fleet.
- *O&M costs:* network providers, labor costs and material for vehicle maintenance
- *revenues:* charging service providers for vehicle use

Design aspects are:

- high reliability of vehicles
- low maintenance costs

The vehicle fleet can be increased as demand increases (scalability). Therefore, during the start-up phase the vehicle costs are less important than the infrastructure costs.

1.2.4.3 service provider

are important as they adapt the TS services to the user's needs.

- *Fixed costs:* offices, computers, etc.
- *O&M costs:* transport providers, administration costs.
- *Revenues:* charging users for the transport services.

Design aspects are:

- system architecture needs to be open to service providers
- to ensure high usage of the system see design aspects of users (Section 1.2.3)

1.2.5 System manufacturer's specific properties and relative advantages

System (and component) manufacturers are at least in part also system developers. A new TS as outlined in Section 1.1 is an innovation leap. Manufacturers will need to develop new systems or production technologies. They will only enter the market if the risk is sufficiently low or the expected profits are sufficiently high with respect to their present activities. Therefore, the adoption need to be facilitated by lowering the risk and development costs. The design aspect are:

- *modular structure of architecture* such that the development risk and costs of the entire system can be distributed amoung many manufacturers. This requires precise specifications in order to assure that the components will work together across the whole system
- *off-shelf components* reduce the development costs and lower risks as they are already in mass production and extensively tested
- *software-tools* allow cost-effective design and performance testing before making major investments into hardware

1.3 General design philosophy

From this sections on we describe the TS itself, starting with general design philosophies. The design process should follow a general *design philosophy*. The design rules below should help in finding solutions, in particular if decisions cannot by uniquely derived from other design objectives.

- high reliability
- highly modular architecture with a high number of exchangeable standardized off-shelf components, where each component has a known, simple and reliable functionality
- well defined, standardized and open interfaces
- easy to maintain, assemble/disassemble, if possible automatically
- the transport network should be extendable qualitatively (with more sophisticated technologies) and quantitatively (network expansion to an arbitrary size)

1.4 Safety, comfort and security

Here we attempt to define general and technological independent criteria for safety, comfort and security.

1.4.1 Safety and comfort

In order to define criteria we need to separate between between two modes of operation:

- nominal operation
- emergency operation

It is assumed that passengers are seated, facing the front, without safety belt.

1.4.1.1 nominal operation

In *nominal operation* we adopt the *comfort criteria* from E. Anderson [6]:

- acceleration at maximum $0.25\,g$ ($g = 9.81\,m/s$) for a duration of maximum $1\,min$
- jerk[1] at maximum $0.2\,g/s$
- no oscillations between *3* and *10 Hz*

For the transport of passengers apply the additional criteria:

- temperature adjustable between $288^\circ\,K$ to $300^\circ\,K$ ($= 14.84^\circ\,C$ to $26.84^\circ\,C$)
- air pressure at $1.01325 \pm 0.101325\,hPa$ ($= 1 \pm 0.1\,atm$)

[1] Jerk is defined as the time derivative of acceleration.

- fresh and clean air, with oxygen contents of above $10\,\%$ (ventilation, smoke-, particle-, or CO_2 filters)

In the event of a longer unplanned system shut-down (power failure, blockage due to vehicle breakdown, e.t.c) there should be provision for rescuing passengers or to get passengers to the next stop or an emergency alighting point within 1 *hour*.

1.4.1.2 emergency operation

If the system is in *emergency operation* mode then *safety criteria* apply. As a general rule:

serious injuries, directly or indirectly caused by the system, should be physically impossible.

In particular:

- maximum deceleration of $0.5\,g$ for seated passenger without safety belt
- temperatures, smoke, and gas should not threaten health or life in the cabin and on escape routes

External damage (vandalism and unauthorized deviation of vehicles, sabotage or natural catastrophes) should be reduced but can be never completely eliminated.

1.4.2 Security and psychology

Security and psychological issues are important, in particular for automated TS because:

- there is nobody near, who can immediately help in case of danger. People may be afraid to use the system by their own
- criminal hackers or terrorists may try to sabotage control and information systems
- some people might get claustrophobic or depressed if vehicles feel too confined

Therefore, the following general design rules apply in order to improve system security:

- *assistance and information systems:* the user must be able to call for assistance at any time, possibly using the information systems that are accessible at stops and inside vehicles
- *passive protection of vehicles and infrastructure:* vehicles and infrastructure should be sufficiently protected against certain violent attacks such as blocking of vehicles by throwing objects on the track, breaking into vehicles, etc
- *camera supervision:* critical locations like stops or areas where vehicles move slowly should have camera supervision or be periodically visited by vehicles that are equipped with cameras
- *isolated information systems:* the system information networks which transmit vital data should be isolated from public networks. Access to internal information should only be possible with a sufficient authentification and only at authorized (physical) locations

- *computer networks and other centralized information systems should not be safety-critical*
- *sensors:* the system should be able to detect damage and inform security staff. There should further be sensors that detect unauthorized intrusion into the internal information system
- *friendly interior vehicle design:* the inner vehicle shapes and colors should give a feeling of security and space Bright colors should be preferred to dark colors.

1.5 Vehicles

The *vehicle* is the moving part of the TS, in which passengers or freight is carried. Satisfying the constraints from Section 1.1 and 1.2, a vehicle should have the following general features:

- *vehicle size* is determined by:
  - minimization of vehicle size[2]
  - space for *four seated adult persons* plus baggage in case of person transport
  - long enough for a tall person to lie down in comfort
  - space for maximum *three industrial pool pallets* Euro tool pallets are 1.2 *m* long, 0.8 *m* wide and 1.44 *m* high. But there should be also sufficient space for equivalent ISO pallets.

  The inner dimensions of the vehicles should be approximately:

  - 1.3 *m* width
  - 3 *m* length
  - 1.5 *m* height
- *payload* of one vehicle should be limited, probably to a value of about: 500 *kg*. This maximum weight is introduced in order to limit the costs and visual impact of the transport system infrastructure. The weight of 500 *kg* corresponds also to the weight of four adults with baggage.
- *vehicle propulsion* should whenever possible performed by electric motors, because they have a high efficiency, are low noise, have no local emission and have also low maintenance costs. The vehicles should take the electrical energy from the track, wherever possible Batteries or other energy storage should only be used when necessary and for short distances. Energy storage systems add to the weight of the vehicle and have high maintenance costs.
- *Vehicle form* should be aerodynamic (target $c_w = 0.3$) and have a futuristic design.

[2]Following E. Anderson [6] and considering only the factors: vehicle cost, guideway cost, energy consumption and average occupancy then the optimum vehicle size is for one person only. If the vehicle is larger, then the solution is from his point of view sub-optimum, but it is more social and has a broader application field which would lead to a higher usage and finally to lower costs

- Vehicles should be able to run:
  - on guideways separated from pedestrians
  - on the ground in areas shared with other vehicles and pedestrians. In this case speed must be limited at walking speed and have fail-safe collision avoidance systems
- Vehicles should be easy to clean and maintain.

Within the above defined vehicle dimensions, payload and safety criteria, the *vehicle interior* should be freely customizable. Below we define the features of standard person and freight vehicles. Standard vehicles represent the vast majority of all vehicles, they are shared and should be everywhere available. For this reason, standard vehicles should cover a large spectrum of transportation applications.

1.5.1 Standard passenger vehicle

A *standard passenger vehicle* is a vehicle customized for the transport of passengers, but needs to accomodate a variety of passenger plus baggage loads in a flexible way.

- *Interior vehicle design:*
  - welcoming atmosphere
  - warms and soft colors, but with (irregular) patterns of a darker color to hide smaller dirt patches
  - fitting without sharp corners
- *Furniture:*
  - at least one of the seats should be situated near the door and be at a height at which an elderly person can set in and out conveniently. At the same time the seats should be acceptable and comfortable for other users, for example a 13 year old child should be able to get into the seat.
  - seats with places for 4 adults or 2 adults with 3 children.
  - seat configuration should allow for enough room such that a adult with a child carriage or the passenger in a wheel chair can enter the vehicle and have easy access to the user terminal.
  - seats should be able to be configured as a bed.
  - there should be provisions to perform basic office work in the vehicle.
- *Luggage capacity:* large enough for four medium sized suitcases. Possibly enlargeable by moving or folding the back seats to the front, so that there is sufficient space for larger objects, such as shopping charts, bikes, small furniture and objects of similar size.
- *All buttons, handles, openers and displays:*
  - should need little physical effort.
  - can be operated and read by a 13 year old child.

  - buttons should be large enough and with an appropriate profile such that visually impaired persons can feel them.
  - Display information should be acoustically available, if desired.

- *User terminal* (see Section 1.7.1) inside the vehicle with keypad and display through which the passengers can communicate with the TS. The user terminal also includes options to interrupt or divert the trip.
- *Emergency break* near the user terminal which is protected against accidental activation.
- *Emergency button* near the user terminal to call for assistance or help.
- *Emergency exit* should allow escape from the vehicle in case the door is blocked.
- *Open-door button* inside the vehicle, beside the door. Its function is to open the door when vehicle is stopped or to prevent doors from closing (similar function to the "open door" button in an elevator).
- *User card reader with display* outside the vehicle, beside the door. The users can insert their user card which will open the vehicle, like unlocking a car. The display shows the user-id number in the case the vehicle is booked (See Section 1.7.5).
- *Green light and buzzer* beside the user card reader, to indicate available or booked (empty) vehicles.
- *Provisions for an ISDN connector* for phone and Internet connection. The necessary ISDN infrastructure is not a part of MAIT .
- *Protection* against persons who try to break in violently.
- *Loudspeakers* to be able to listen to system messages or passenger supplied audio sources, if desired.
- *Smoke and damage sensors*.

1.5.2 standard freight vehicle

The standard *freight vehicle* has the dimension of the standard passenger vehicle but it is empty (apart from fixing points for containers) and has no user terminal. See also Sections 1.7.6 and 1.7.7. The standard freight vehicle has the following features:

- it can be completely controlled by external user terminals, including:
  - door locking and unlocking
  - door opening and closing
- door opening and closing buttons outside the vehicle, beside the door. The door open button opens the door if the vehicle is unlocked. The door close button shuts the door when loading is completed (see Sections 1.7.6 and 1.7.7)
- an emergency door open button inside the vehicle to allow a person to escape in the event of being trapped inside

- easy to load and unload three standard industrial pallets
- support for automatic loading and unloading. Here the user-terminal can be a computer that controls:
  - door opening and closing of vehicle
  - loading or unloading freight. This is done with TS external facilities. However, standardization would be useful also for those facilities
- vehicle should be suitable for indoor transport

1.6 Infrastructure

The *infrastructure* means here the *visible* fixed part of the TS that is require to run the vehicles, hence:

- *track*s: these are guideways, rails, roads or whatever is necessary to control a vehicle to its destination A special element of the track are stops (see Section 1.6.4); *stops*, are stations where vehicles halt to let passengers in and out or to (un)load freight
- *support structures for tracks* like columns, stays, bridges and tunnels

The infrastructure should have the following general features:

- the passengers or goods being transported should be able to reach any point of the network without intermediate transfers from one vehicle to another
- the track should provide *cost effective* and *high quality transport* (see Section 1.4.2) *for all transport applications*, including door-to-door, indoor, inter-urban and inter-city connections (for more details, see subsections below)
- the infrastructure should visually fit into city architecture or landscape
- security-critical parts of the infrastructure should be permanently camera supervised
- the design should look well designed and elegant

It is apparent that *there is not one type of track satisfying all conditions*. The infrastructure of the TS should be designed such that it can be adapted costs, capacity, flexibility and speed.

1.6.1 infrastructure for local door-to-door and in-door transit

This transport category stands for short distance transport; for example, from a residence to the local shopping center or indoor transport. The infrastructure for this application should have the following features:

- travel distances up to $5\,km$
- maximum speeds of $25\,km/h$, walking speed when space is shared with pedestrians
- high flexibility: can be highly branched, with short distances (several meters) between stops, merges, or diverge points

- compact: branches and stops take up the minimum of space
- low to medium carrying capacity
- low cost where low usage
- safe for small children travelling unsupervised
- option for overhead guideways for in-door applications with heavily used floor space

1.6.2 infrastructure for inter-regional and inter-urban transit

The infrastructure for this application should have the following features:

- travel distances typically from 1 *km* to 50 *km*
- line speeds from 60 *km/h* to 130 *km/h*
- stops, merges or diverge points typically every 1 *km* to 10 *km*
- high carrying capacity
- compact guideways in city centers
- low visual impact
- separation from pedestrians

1.6.3 infrastructure for inter-city and inter-national transit

The infrastructure for this application should have the following features:

- long-distance: typically greater than 50 *km*
- high speed: faster than 130 *km/h*. There is no reason to set a maximum speed as long as safety and comfort criteria are satisfied (see Section 1.4)
- simple network topology: few stops, merge or diverge points
- medium to high carrying capacity
- separation from pedestrians

1.6.4 Stops

Depending on the type of track, the appearance of *stop*s can change significantly. They all have in common that the platform from where vehicles are loaded and unloaded is flush even with the bottom of the vehicles. There are:

- single berth stops which operate independently from one another even when they are close together
- multiple berth stop where vehicles can be loaded in parallel, which requires coordination of both vehicles and passengers

Passenger stops will usually be different to freight stops.

1.6.4.1 passenger stops

All *passenger stop* must be accessible by the deaf, blind and disabled. Optionally, passenger stops can be equipped with:

- a stop-type or call-type *user terminal* (see Section 1.7.2) for programming of trips or for calling vehicles (for details see Sections 1.7.1, 1.7.4 and 1.7.5)
- *passenger boarding facilities*: passenger boarding facilities are useful for multi-berth stops for organizing and controlling the parallel boarding of a large number of passengers. A generic boarding facility is sketched in Fig. 1.2. Boarding facilities can be designed in various ways as long as they satisfy the following conditions:
  - Among the passenger(s) in the waiting zone is one user whose user id is known to the system
  - the passenger(s) in the waiting zone will enter the vehicle that corresponds to this waiting zone

  Both conditions can be satisfied, using an electronically gate that unlocks when a user inserts his travel card into the travel card reader of the boarding facility, (see Fig. 1.2)

1.6.4.2 freight stops

Freight stops are simply places where freight can be loaded or unloaded (manually or automatically). Optionally, Freight stops can be equipped with:

- a stop-type or call-type *user terminal* (see Section 1.7.2) for programming trips or for calling vehicles (for details see Sections 1.7.1, 1.7.6 and 1.7.7)
- *freight loading facilities*: freight loading facilities are used for the automated loading or unloading of freight (for example standard industrial pallets, packages, letters etc) Freight loading facilities can be designed in various ways as long as they satisfy the following conditions:
  - user id of the user who is responsible for the transport of this particular freight at this stop is known to the system
  - the freight that is loaded with this facility enters the right vehicle

  Both conditions can be satisfied when a computer system controls and coordinated loading as well as the programming of the destination (see computer-type user terminal in Section 1.7.2)

Freight transport operations are explained in Sections 1.7.6, 1.7.7)

1.7 Operation

The operation, including trip-planning, ticketing and billing, should be:

- *less complex than driving a car or using present public transport*

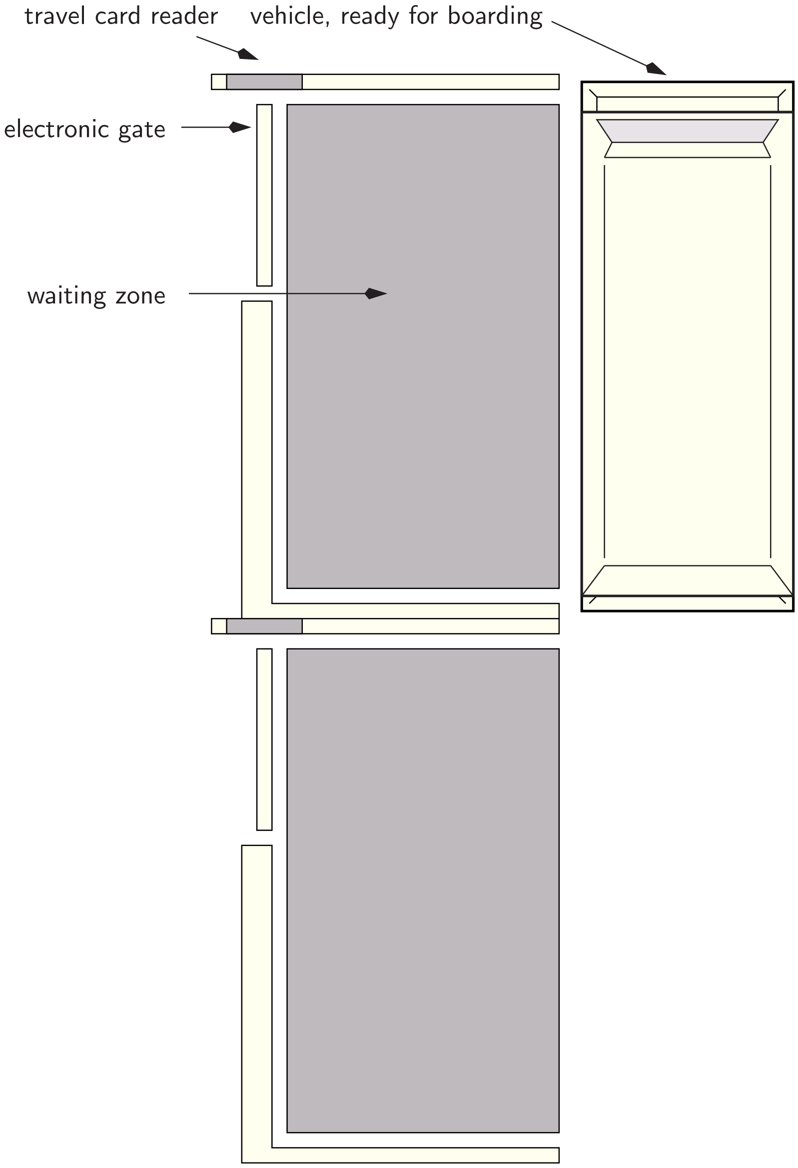

Figure 1.2: Sketch of a generic boarding facility.

- *intuitive for the user* but technically realizable at low cost
- *similar to the operation of known automatic machines* such as cars, phones, elevators or ATMs (whenever possible)

Because the new TS should offer a broad choice of services and options its operation may become complex and it is desirable to have a service that provides an "easy to use" interface between the TS and the user. This service is called the *user-management*. The introduction of a user-management has also economical reasons, since it is intended that several companies compete for the simplest, costumer-oriented and most transparent travel service. The user-management and the type of services it should offer are defined below.

Remark 1: The system operation explained in this section is based on a user-card. This is a card in the format of a credit card with which the user can identify himself electronically. It is thought that this is the most cost-effective solution with current technology.

Remark 2: The exact human-system interaction and boarding procedures are subject to behavioral tests.

1.7.1 The user-management

The *user* is a person who going to use the new TS, for either passenger or freight transport. He will need to open an account at a *user management* of his choice.

1.7.1.1 Services

The user-management, should act as a "travel agent", providing the following services:

- the user-management hands out a *user-cards t*o the users with a unique *user identification number* (*user-id*). The user card has the dimensions of a standard credit card and has a chip on it to store the user-id and the identification number of the user-management
- the user-management is the *only responsible for planning, organizing, and billing of each trip* that the user will undertake on the account of the corresponding user-management
- the user-management is the *only institution with whom the user communicates, before, during and after each trip* with the TS
- The user-management *will accept and process the following orders from the user*:
  - selection of destination for a single vehicle
  - organization of vehicle cleaning when the user tells the system that the vehicle needs to be cleaned or when the user refuses the vehicle because it is littered or damaged
- the user-management *may provide special services* such as:
  - booking or organizing passenger (Sections 1.7.5) or freight trips (Sections 1.7.7)
  - diverse travel options (see Section 1.7.1.3)

  Furthermore, clever user-managements will try to predict the user's travel habits. For example, if a user leaves his house every morning at 7:00 the user-management could organize a vehicle that is already waiting for him.
- tracking and charging persons who litter or damage vehicles

1.7.1.2 Orders

The user can give orders to the user-management such as:

- selecting or alternating the destination of the next or current trip
- refusing to use a vehicle (if it is littered or damaged)

- sending vehicle for cleaning after use
- booking a person transport
- organizing a freight transport or
- changing travel options

1.7.1.3 Travel options

Different user-managements may offer a different choice of *travel options* that can be selected by the user. Dependent on the selected travel options, the user will need to provide the appropriate information to the *user-management*. These options can be modified at any time via user terminals at stops, via Internet, cellular phone or by contacting directly a costumer office of the user-management. Here is a possible choice of options:

- *a default destination:* this will be the destination for each trip unless the customer specifies a different one
- *vehicle type:* where possible, user services will book a vehicle with different interior. This can be any non-standard vehicle type (see Section 1.5), including the users own private vehicle
- *operation:* user-system interaction can be modified:
  - *passengers with wheel-chairs or with child carriages* the seats fold back automatically when passengers enter the cabin
  - For the *visually impaired* all system messages, such as destination station, door closing, *come from loud speakers* in addition to displays or visual signals. Special messages could be added to help improve the journey.
  - *the physically disabled and elderly people,* cabin doors would not close too quickly to allow them sufficient time
- *route selection.* One has the option to:
  - select the path that minimizes travel-costs
  - select the path that minimizes travel-time
  - select the path with a scenic view
- *language selection:* all system information are displayed or spoken in the selected language
- *defining alias names for destinations:* the customer can define alias names instead of numbers for frequently accessed destinations
- *transport of minors:* When minors are on board without adult supervision, some functions of the user terminal can be blocked
- *Waiting time of booked vehicles:* This is the time booked vehicles wait for the user before leaving without them (see Section 1.7.5)

1.7.2 User terminals: the user's access point

The user has access to the user service via *user terminal*s which is a general term for a variety of devices that allow the user to communicate with the user-management in a unified manner. The way information is received and orders given is the same for all user terminals—within the technical limits of the particular terminal type. Examples of user terminals types are:

- *stop-type user terminal* with keypad and display. The display is sufficient to list menu items and small messages. The key pad has:
  - *menu buttons* to navigate through menus and select items
  - *numeric keys* to insert destination numbers (or others)
  - *help*, to call for assistance (menu sensitive)

  This type of user terminal would usually be installed at frequently used stops. Their operation should be similar to the one of a banking machine (ATM): The user inserts his travel card into the slot of the travel card reader and gives interactively (menu-driven) his orders to the user management. The user-id and user-management-id are stored on the travel card. Thereafter he'll take back his travel card. In the same manner, stop-type user terminal can be used to call empty vehicles.

- *call-type user terminals* without keypad and display. This is a simple box with a travel card reader that may be installed at less frequently used stops. When the user inserts his travel card, the appropriate user-management will direct an empty vehicle to this stop. Optionally there is a small display, indicating the waiting time.

- *Cabin-type user terminals*. Those are similar to stop terminals but the key pad and the display are inside the cabin and the travel card reader is outside the cabin, beside the door (where one would usually expect to open a vehicle with a key). The key pad is enhanced by the *interrupt button* to exit at the next available stop. When the user inserts his travel car and is authorized (cabin is empty or booked for him) the vehicle door opens. If desired, the user can make orders inside the vehicle, just as with stop terminals. After the trip, the user takes back his travel card. There should also be the possibility to feed the travel card reader automatically with wayside boarding facilities.

- *WWW-type user terminal*. This is the managemen web site which can be accessed via computer or cellular phone. The user makes his orders by filling in HTML forms. For this purpose, he also needs to insert his user id.

- *Phone type user terminal*. The user can call in one of the user-management's agencies by ordinary phone. The user's id and orders can be selected by pressing the telephone keys while getting orally guided through a menu. There is also the possibility to ask an operator for assistance.

- *Computer-type user terminal*. This terminal allows to give orders to the user-management by a computer via standardized e-mails. This means that a computer can generate automatically orders and process messages from the user-management. This is useful:
  - if the transport includes many vehicles that need to be coordinated

- if the computer needs to coordinate vehicle and automated loading and unloading facilities
- for periodic or auto initiation of transport orders. This feature is necessary to include the new TS into industrial production processes

1.7.3 Terms and general philosophy of vehicle operation

- The travel card is used to identify which user is using the vehicle(s). This user is responsible for loading and unloading and the appropriate use of the vehicle i.e. that the vehicle is not damaged or littered by passengers or freight. If the user recognizes an improper state of the vehicle he is supposed to inform the user-management (who will take care of maintenance).
- There is a simple operating philosophy that should guide users through the entire procedure of a trip:
  - *a green flashing light* at buttons or other devices indicate that the user *has to* press or access one of them in order to go ahead with the procedure of the trip
  - *a constant green light* at buttons or other devices indicate that the user *has the option to* press or access one of them in order to go ahead with the procedure of the trip
  - *a constant red light or no light* at buttons or other devices means that the respective functions or devices are inactive or out of order

  For visually impaired persons there is either a vibrating plate beside each light (usually for all buttons and devices at stops, outside the vehicle), or instructions are given via loud speakers (inside vehicles).
- *The trip destination is programmed before entering the vehicle.* The *destination programming* can be done in two principle ways:
  - the user gets in contact with his user-management (using any user terminal, except call-type and cabin-type user terminals, see Section 1.7.2) and gives the necessary orders (see also orders in Section 1.7.1)
  - if no destination has been specified when the user enters the cabin then the *default destination* is used. It is compulsory for the user to specify a valid default destination upon the reception of the travel card in order to guarantee that the vehicle immediately knows where to go as soon as the user entered (see also travel options in Section 1.7.1)
- an *Available vehicle* is a vehicle that is empty and not booked. Everybody with a valid travel card can enter an available vehicle. A vehicle indicates its availability in one of the following ways:
  - at *stops without boarding facilities* (see Section 1.6.4) the vehicle has a green flashing light beside the door, near the slot of the travel card reader, where the user is supposed to insert his travel card. For standard freight vehicles the green flashing light is outside the vehicle beside the door open button

  - at *stops with boarding facilities* (see Section 1.6.4) there is a green flashing light at the travel card reader of the boarding facility (see Fig. 1.2). If there are passengers inside the waiting zone (who already identified themself by means of the travel card reader) then the vehicle doors open immediately upon the arrival of the vehicle

- a *booked vehicle* is a vehicle that is empty, but booked for a user with a specific user id. Only the user with that user id can access the vehicle. The booked vehicle is also indicated with a green flashing light, just as the available vehicle, with an additional small display below that indicates the user's id

1.7.4 Spontaneous travel

The entire procedure of this trip happens in three logical steps:

Step 1: *specification of destination:* It is assumed that destination is programmed *before* entering the vehicle. The user has principally two possibilities select a destination:

- the user gets in contact with his user-management (using any user terminal, except call-type and cabin-type user terminals, see Section 1.7.2) and gives the necessary orders (see also orders in Section 1.7.1)
- if no destination has been specified when the user enters the cabin then the *default destination* is used. The default destination is a travel option that can be changed at any time (see Section1.7.1.3)

Step 2: *entering vehicle:*

1. the user needs to go to a MAIT stop
2. dependent on the type of passenger stop (see Section 1.6.4) the user accesses an *available vehicle* in one of the following ways:
   - *stop without boarding facility:* In the case there is no available vehicle, the user accesses a stop-type terminal or inserts his card into a call-type user terminal in order to call a vehicle. Then the user inserts his travel card into the reader of the available vehicle. The travel card is returned immediately, and as soon as the user takes it out of the slot, the vehicle's door opens
   - *stop with boarding facility:* The user inserts his travel card into the slot of the card reader of a boarding facility (see Fig. 1.2) with a green flashing light. The user will pass with accompanying persons and baggage through the gate into the waiting zone. The gate is locked as soon as the user takes back his travel card from the slot. If there is no available vehicle at the platform, the passengers need to wait. The vehicle doors open as soon as it arrives
3. The user can now enter the vehicle with accompanying persons and baggage

Inside the cabin, the display of the internal user terminal shows the destination of the current trip. The vehicle door closes after a moment and the voyage begins.

The user can change destination or travel options (see Section 1.7.1.3) at any time via the internal cabin-type user terminal [3]. The user has the option to stop the journey at

[3] It may turn out that people prefer not to program any destination before, to start with the default destination and to program their trip inside the cabin, *after* starting the trip

any time by pushing the "abort" button. In this case the vehicle exits at the next free stop.

Step 3: *leaving the vehicle.* After arriving at the destination station:

1. the door opens
2. the user vacates the vehicle
3. the vehicle attempts to close the doors after all passengers left the vehicle[4]
4. the user-management charges the bank account associated with the card's user id

1.7.5 Booked travel

A booked person transport should happen in the following steps:

Step 1: *booking:* the user gets in contact with the user-management (as explained in Section 1.7.2) and selects interactively:

- origin and destination stop of intended trip. The stop of origin can only be a stop, where a waiting vehicle does not block other vehicles
- the departure time of intended trip
- other (non standard) options like number or type of vehicles

Step 2: *entering vehicle:*

1. the user goes to a MAIT stop, where the booked vehicle(s) is(are) waiting. If the user does not arrive in time, the vehicle will wait. After a certain time, which is also a travel option (see Section 1.7.1.3), the vehicle will leave the stop without its passenger
2. dependent on the type of passenger stop (see Section 1.6.4) the user accesses the *booked vehicle* in one of the following ways:
    - *stop without boarding facility:* a small display beside the vehicle door indicates the *user-id* of the costumer who booked this vehicle. Then the user inserts his travel card into the reader of the vehicle. The travel card is returned immediately, and as soon as the user takes it out of the slot, the vehicle's door opens. In the case the user booked multiple vehicles, the doors of all vehicles open simultaneously when inserting the user card into the slot of one of the booked vehicle
    - *stop with boarding facility:* a small display at the boarding facility's card reader indicates the *user id* of the costumer who booked this vehicle (see Fig. 1.2). The user inserts his travel card into the slot of the card reader. The gate will open if the user's id is identical to the displayed one. The user will pass with accompanying persons and baggage through the gate into the waiting zone. The gate is locked as soon as the user takes back his travel card from the slot and the vehicle doors open

[4]The "empty vehicle detection" could be realized with weight sensors, which are also necessary to prevent overload

3. The user can now enter the vehicle(s) with accompanying persons and baggage.

Inside the cabin, the display of the internal user terminal shows the destination of the current trip. The vehicle door closes after a moment and the journey begins.

The user can change destination or travel options (see Section 1.7.1.3) at any time via the internal cabin-type user terminal. The user has the option to abort the journey at *any* time by pushing the "abort" button. In this case the vehicle exits at the next free stop.

Step 3: *Leaving the vehicle:* After arriving at the destination station,

1. the door opens
2. the user(s) vacate(s) the vehicle(s)
3. the vehicle(s) attempt(s) to close the door(s) after all passengers exit
4. the user-management charges the bank account associated with the card's user id

1.7.6 Spontaneous freight transport

A *freight transport* in the strict sense is a *freight only transport*, where the user does not travel with a (standard or non-standard) *freight vehicle* but controls it via a user terminal. This would usually be a computer-type user terminal (see Section 1.7.2). A spontaneous freight transport assumes that freight vehicles are available at the departure stop. This may be a usual situation in a factory, where empty freight vehicles are waiting in a queue to get loaded. Alternatively, vehicles can be called by stop-type or call-type user terminal, similar to the spontaneous passenger transport. Empty vehicles can be ordered, using the procedure of the booked freight transport, described in Section 1.7.7. The entire transport should happen in three logical steps:

Step 1: *specification of destination:* The user, which could be a computer communicates the origin and destination stops to the user management. The user-management will then verify whether the vehicle which parks currently at the stop of origin is empty and available If so, it will unlock it for loading.

Step 2: *loading the vehicle:*

1. the vehicle door is opened by:
   - pressing the door-open button
   - telling the user-management to open the door via user terminal
2. the vehicle can be loaded either manually or automatically with the appropriate *loading facilities*
3. the loading process is terminated by:
   - pressing the door-close button
   - telling the user-management to close the door via user terminal

After the doors are closed and locked, the vehicle will start the trip. At any time, the user, who is not inside the vehicle, can change transport destinations interactively by contacting the user-management as described in Section 1.7.1

Step 3: *Unloading the vehicle:* After arrival at the destination, user-management unlocks the vehicle doors. The user has the option to keep the vehicle locked until he wishes to unlock it (for example if he wants first a confirmation from the destination that the vehicle is ready for unloading).

1. as soon as the vehicle doors are unlocked, they can be opened by:
   - pressing the door-open button
   - telling the user-management to open the door via user terminal
2. the vehicle can be un-loaded either manually or automatically with the appropriate facilities
3. the un-loading process is terminated by:
   - pressing the door-close button
   - telling the user-management to close the door via user terminal

The user-management charges the users bank account.

1.7.7 Booked freight transport

Step 1: *Booking:* the user which could be a computer, contacts the user service via a user terminal (as explained in Section 1.7.1) and selects interactively or by standardized protocols:

- origin and destination stop of intended freight transport
- The departure time of intended transport
- Other options like number or type of vehicles

The user-management will then direct the requested empty vehicle(s) at the desired time to the departure stop and unlock it(them). From now on the booked freight transport is identical to the spontaneous freight transport (see Section 1.7.6), except that there can be more than one freight vehicle.

Step 2: *Loading the vehicle(s):*

1. the vehicle door(s) are opened by:
   - pressing the door-open button
   - telling the user-management to open the door(s) via user terminal
2. the vehicle can be loaded either manually or automatically with the appropriate facilities
3. the loading process is terminated by:
   - pressing the door-close button(s)
   - telling the user-management to close the door(s) via user terminal

After the doors are closed and locked, the vehicle will start the trip. At any time, the user, who is not inside the vehicle, can change transport destinations interactively by contacting the user management as described in Section 1.7.1

Step 3: *Unloading the vehicle(s):* After the arrival at the destination, the user-management unlocks the vehicle doors. The user has the option to keep the vehicle locked until he wishes to unlock (for example if he wants first a confirmation from the destination that the vehicle is ready for unloading).

1. As soon as the vehicle door(s) are unlocked, they can be opened by:
   - pressing the door-open button
   - telling the user-management to open the doors via user terminal
2. the vehicle can be un-loaded either manually or automatically with the appropriate facilities
3. the un-loading process is terminated by:
   - pressing the door-close button
   - telling the user-management to close the door(s) via user terminal

The user-management charges the users bank account

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