There are several generations train ticket vending machines.

a) In the buttons phase the problems are anthropometric and perceptual (pressing keys and readability of information). Ergonomics solves these problems.

b) The frame button phase showed that frame buttons might be applicable for issuing bank notes but not for train tickets.

c) Touch screen technology is more appropriate for public use of complex systems like train ticket vending. To prevent problems cognitive psychology should be leading.

d) In the electronic card phase, the options for tickets and prices increase. When the travel products to be sold are based on traditional marketing principles communication of relevant travel information becomes impossible.

e) When the train ticket vending system survives the electronic card system systems will become integrated. What are cognitive psychological requirements for this generation?

Keywords
Interface, passenger, payment, psychology, usability.

1. Introduction
The past unveils the future of TVMs (ticket vending machines). These machines evolved in several decades from ‘physical one-product–one-coin-machines’, towards ‘non-physical contactless invisible electronic systems’. The latter has no buttons, no screens and … maybe there is no need for interface designers. However, this analysis shows that for future systems there are new requirements and there is a lot of work to do for interface designers.

2. The buttons phase

2.1 The interface technology
In the ‘One-coin-one-product-phase’ interface design was no problem. The system is so simple and physical, that buying a ticket is easy (Figure 1). Real problems came when the number of buttons, the number of products and the ways of payment increased.

2.2 The problems
When controls are electronic, the size can be decreased and problems with the operation arise. Fortunately for these problems, science could give straightforward requirements for button size, character size and luminance contrast. An extensive
investigation for NS, observing hundreds of train passengers with a hidden camera (Figure 2), revealed that in the multiple-buttons-and-text-machine-phase (Figure 5) interfaces proved to be more difficult to design than psychologists could predict (Verhoef, 1986). Some of the results:

a) 11% of the passengers pressed destination instead of the white button on the right.

b) 0.3% of the passengers bought a ticket to the wrong destination. Half of these passengers selected a destination that was one line higher or one line lower than the destination they intended to press (Figure 3).

c) There were several observations that have shown that passengers did not press the button of the class they intended to press. For instance, 1% changed class before payment and at least 0.15% of the passengers bought a ticket of another class than they intended (n=426). The distance between class indication and button was between 2 and 11 cm.

d) 50% of the passengers do not notice an ‘Out of order’ message and they proceeded to select their destination (n=426). The visual distance between the first step: ‘selecting a destination’ and the second step ‘noticing the text ‘Out of order’ (in red in the price display’), was approximately 40 cm.

These are some of the problems caused by not taking account of the effect of visual distance but understanding was a problem too (Verhoef, 1986).

2.3 The solutions

To solve the problems with the buttons-phase B100 ticket vending machine (Figure 5) different strategies were chosen.

a) The machine was designed by Autelca, a company based in Switzerland. It is unclear what ergonomic principles were applied. The Swiss Railways informed NS at that time that they were satisfied because the text on the machine met their requirements for readability.

b) A text solution including several hundreds of words to explain the operation, was chosen in Germany (Geiser & Reinig, 1980; H.Reinig 1986; Reinig, H-J., & Wergles, K., 1984). The Japanese Railways preferred the same solution (Oda, 1985). The text solution became a DIN for German public transport ticket vending machines. A Swiss evaluation rejected the solution (Felix & Krüger, 1989). The approach was abandoned in Germany ten years later (Sandmaier, 2008).
c) Netherlands Railways did not apply text to change physiology of passengers but applied psychological principles and changed the machine, for instance by reducing visual distance (Figure 4). On the next generation machines, the textless B8060, hardware was changed to meet more psychological requirements (Figure 7.)

3. The frame button phase

3.1 The interface technology
The first screens for public systems were the frame button screens for issuing banknotes.

a) Up to 1995 frame button interfaces were preferred over touch-screen interfaces because several problems were unsolved (costs, vandal proofness).

b) Frame buttons have an obvious input technology that is easy to understand by users and easy to develop for designers. You have hard buttons which are familiar and easy to recognize, and the screen enables you to present variable texts for the buttons. The buttons dictate the position of the information, there is no discussion on the arrangement of the information. With very little hardware the system can present far more options than the traditional buttons machines.

3.2 The problems
A psychological analysis (Verhoef, 1999b) has shown that screens with frame buttons solves technical input problems but create psychological problems that are hard to solve for the interface designer. What are these problems?

a) At that period, frame button interfaces were a success for issuing banknotes. For many ticket vending machine experts this was the solution for ticket vending. However:
   - The task to perform at a TVM is: insert card, enter pin code, enter amount and take out your card and your money. Even at that time ticket vending was much more complex.
   - It was expected that banks do not improve TVMs for customers. This assumption proved to be correct; today’s TVMS are the same as TVMs ten years ago. So there is no need for a flexible technology that can cope with more and unforeseen functions.
   - For the frame button TVMs it was easy to win from the rather userunfriendly alternative (queuing for the wrong window at an inconvenient moment).

b) Designers think that users do not understand that a touch screen should be touched. They try to help using conspicuous texts and realistic buttons (Figure 8). We tested the premise that the input problem with a touch-screen interface was a really a problem. Of all passengers, including many elderly passengers not having used any screen technology, 0,0% has problems pressing a button on a touch-screen (Verhoef, 1999a). Touching is not the problem and costly attention attracting and graphics should not be used to solve a not-existing problem.

c) The main problem of frame button interfaces is that simply indicating the meaning of a button, determines completely the visual structure of the interface. The buttons dictate a structure of lists adjacent to the frame. This impairs the solution of the less obvious real problems, for instance having an overview of the parameters to be selected and changing parameters of the product selected in an earlier step.
3.3 The solutions
The conclusion for NS was clear: no solution using frame button technology.

4. The touch-screen phase

4.1 The problems
The main problem at that time with screen technology was that screen interfaces had a rather bad usability reputation. Professional users had to accept bad usability but as a public transport organization one cannot force every passenger to adapt himself to an awkward technology.

4.2 The solutions
NS solved the usability problem using available research performed on previous generations of ticket vending machines and more general cognitive psychology. Graphical design and technology had to operate within cognitive psychological requirements. Psychology was not used afterwards to establish that passengers do not understand the machine.

The main problem is routing – i.e. steering the user through the sequence of sub-tasks that have to be performed to acquire a ticket. On hard button vending machines, for technical reasons, it is impossible to install controls in positions that are the best from a psychological point of view (top-bottom or left-right).

On screens there is a logical solution for this problem: give each step its own window and present them sequentially as is done by wizards (Figure 9). However, following a sequential procedure is not how people generally operate. In addition, a sequence of windows does not give an overview of the steps done and the steps to be taken. Changing selections made, is a problem too. Hierarchical and sequential procedures cause the well known navigation problem.

In practice the language function can easily be made parallel in stead of sequential, using a permanent ‘change language’ button. Observations at Schiphol Airport Station show that this button is not pressed as a first step.

The routing problem also can be solved in a non-sequential and non-hierarchical way. The solution is presenting the controls belonging to one task conspicuous and immediately adjacent to the fixation point of the previous step (Figure 9).

In this machine there was more cognitive psychology implemented than selecting language and routing.

a) Parameters could be changed at any time, without returning to the main menu or pressing cancel.

b) The list of stations included synonyms for stations having several names, for instance ‘Den Haag’ and ‘s Gravenhagen’ (presented in the list under the letters D, H, S and G).

c) In a list, a group of stations (e.g. all Amsterdam stations) was not broken up but
presented in one column. Because of that, the design for the list looked frayed but the number of errors selecting a station was in some cases reduced with 4%.

4.3 The evaluation
The interface was tested in several ways.
a) After tests with several hundreds of passengers the answer to the question: “Is the touch-screen TVM user-friendly?” proved to be: “Yes, even for people 90 years of age and hardly being able to travel anymore.”
b) There was no need to change the first concept of the interface after the tests in 1998. Today, after more than ten years complexity is multiplied (tickets for dogs, bicycles, round trips, starting at another station, tickets for abroad). The concepts will certainly not be changed. An evaluation of the interface shows that for electronic ticketing of the next future the concept is still valid.

5. Electronic card phase

5.1 The interface technology
For all public transport in the Netherlands in 2009 one system of contactless electronic ticketing will be introduced. Having such a card you can enter anywhere in the Dutch public transport system and exit any where. No paper tickets, no ticket windows, no ticket vending machines, no value cards out of the pocket nor being skimmed.

5.2 The problems

5.2.1 One travel product – one payment card connection

The problem
The system, as it was designed by the suppliers, provided in a rigid connection between the travel product and the card product. The travel products specified by the passengers can only be loaded on the same card that is used for payment. This is not compatible with the way passengers sometimes organize their payment; especially when travelling in groups. Families in most cases, have one person who pays but the system requires each person to have a valid ticket.

The solution
The rigid travel – card connection problem was solved on a technical level by a special application designed by NS. It will be possible to put travel products on other public transport chip cards than the card that is used for payment.

5.2.2 Confusion with other payment systems

The problem
There are differences between the travel chip card and other electronic value cards the users know. There are differences in:
a) deposit on the card: yes/no,
b) access to bank account: yes/no,
c) number of products on the card: money only/several train tickets as well.

The only information the card shows is: “This is a public transport chip card.” You can’t see it is a traditional single train

<table>
<thead>
<tr>
<th>New card no budget</th>
<th>Load € 5</th>
<th>1 card</th>
<th>Pay with coins</th>
</tr>
</thead>
<tbody>
<tr>
<td>New card with budget</td>
<td>Load € 10</td>
<td>2 cards</td>
<td>Pay using pincard</td>
</tr>
<tr>
<td>Increase budget</td>
<td>Other amount</td>
<td>3 cards</td>
<td>Now buy train ticket</td>
</tr>
<tr>
<td>Card history</td>
<td></td>
<td>4 cards</td>
<td></td>
</tr>
<tr>
<td>Card contents</td>
<td></td>
<td>5 cards</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>6 cards</td>
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<td></td>
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<td>7 cards</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>8 cards</td>
<td></td>
</tr>
</tbody>
</table>

Figure 8. The passenger wants to buy a new card and load this card with 10 euro. Now he has to indicate how many cards he wants. (experimental design)
ticket 2nd class to Amsterdam. The interface is invisible as Norman (1998) predicted.

The solution
The original interface was an interface made for selecting parameters of a travel product. It could be used for any other product having parameters. Consequently, there is no need to make any changes in the interface concept of the current interface as can be seen in Figure 10.

5.2.3 The interactions between the products

The problem
The interface as it was specified in 1998 can present any product having several parameters that subsequently have to be set. The interface cannot deal with two of those products at the same time when there are interactions between the parameters of these products. In Figure 10, column 4 you can see one link to the travel product (‘Now buy train ticket’).

a) For instance, it is unclear where to start. There are two options. Starting with detecting the card enables the interface to anticipate on what the passenger needs. However then there is a need to have the card present all the time: for the specification of the travel product or the specification of the card product. This is uncomfortable and unsafe.

b) When the travel product is specified it can become clear that the budget on the card is too low or that there is no space left on the card for that product.

c) Usually a card has to be presented once, in the payment phase. Now the card has to be presented twice. The first sweep is to read the card to know the options that apply for this card. During the second sweep the products chosen are written on the card. Tests show that 16% forgets the second sweep and consequentially the product chosen is not written on the card. The error is not noticed and fatal. The gate will not open or the train conductor will conclude that the passenger has no ticket. A one sweep procedure is not a solution.

The solution
It is said that when the passenger does not adapt to the interface that’s bad luck for the passenger. This strategy is common practice in interface design. However, the answer of NS is: “That is bad luck for the interface designers. Solve the problem.”

The first generation was not-sequential and not-hierarchical and could deal with the functions added in the past ten years. Mixing the travel product with the money product demands for extension to multidimensional interfacing. That is what is being developed now and will solve the problem.

6. Integration phase

6.1 The interface technology
Today you clearly can see that the traditional ticket window is disappearing and that the ticket vending machines, as we know them now, will disappear more and more. However, the travel system including payment and schedules will be there in many phases to come.

The interface problems in each phase are different: anthropometrical (buttons easy to press), physiological (readability), understanding and learning (screen and card technology). Not having solved the problems of previous phases will obscure the results of the current phase. When too much errors are made because the buttons are ill designed (a problem of the buttons phase), one will not well be able to evaluate
a vending machine selling electronic travel cards. Let’s assume that the problems of the previous phases have been solved. Which problems are left?

6.2 The problems

6.2.1 Reliability
One requirement for any system is its reliability.

a) Technology should be reliable but the procedure should be reliable too. Starting a procedure the passenger should arrive at his aim without any technical, procedural, bureaucratic or ergonomic obstacle.

b) The price system should be reliable in that sense that the passengers should not select an expensive ticket when there is a cheaper option for him. That is an unsolved problem for several decades already.

c) Passengers and politics demand the simple and easy to understand requirement that trains should drive as specified in the timetable. That requirement made sense some decades ago when timetables were fixed for one year. Mostly they were printed on paper and distributed all over the world. The limits of paper technology imposed this ‘year-thinking’.

Today 100% reliability of a schedule is more and more difficult to accomplish. It might even be inefficient. The traditional philosophy is that unreliability does not exist and the priority rules train traffic control applies are hidden for passengers. However, unreliability of the schedule should be accepted, controlled and communicated to the passenger. It should be present in travel information and ticket selecting systems (e.g. traditional ticket vending machines or internet ticket vending sites).

6.2.2 Interaction

In the old days public transport systems noticed that there was too little capacity for transport after having performed the transport. Today they can notice that now using vending machines and gates. With tomorrow’s technology this information can be available before the transport is carried out. This enables the system to prevent having too little capacity for transport. Today off-peak reductions are rather rigid; it is a contract for a year and the off-peak hours are fixed, for all lines, the same for all passengers and the reduction is the same for everybody.

The price-capacity trade-off should be used to optimise capacity and cost-comfort for passengers. This should not be done on a yearly basis, for all passengers the same, at fixed time slots and with fixed rates but based on now, this passenger and this public transport situation.

a) The moment/price trade off should be presented when the trip is planned, e.g. when using a travel planner. When buying a ticket using internet there should be an option like: “I will take this trip and get a discount for deciding now.” Ticket vending machines do have a date function already; however, this is not intended for this purpose. Another moment is when the ticket is bought, e.g. at the ticket vending machine.

b) The gates should be able to present more information than: “Beep” meaning: “OK you can enter”. The gate might also say: “10 minutes later your trip would be 10% cheaper”.

c) When the system is connected to the mobile system of the passengers interactive, individual, during travel, communication is possible. This communication will go far beyond today’s practice of communicating disturbances to passengers’ mobile devices.

6.3 Solutions

One solution is the marketing product strategy. The designer develops fancy named and attractive visualised travel products like Thalys and Eurostar. The attractive
visual appearance hides complex travel parameters (destination, price, travel time, travel moment, delays, and reliability) and their trade offs. Political developments encourage the stand alone travel products.

NS applied another solution, developing ticket vending machines. Using cognitive psychology it was no problem to sell complex travel product using ticket vending machines. Using cognitive psychology it will be no problem to guide passengers smoothly through efficient, complex, integrated future schedule and price systems.

Will the passenger become a slave, being forced to adapt his unchangeable psychological functions to traditional marketing communication? Or will the passenger become a free man to whom the options of a complex public transport system are adapted to his cognitive functions in such a way that he easily can select the option that meets his requirements best? History shows that slavery has no future.

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