APCS and the collection of ridership data

Georg König from INIT (Innovations in Transportation) examines the current methodology in charting and analysing ridership data – and how a simple but innovative technique is even looking at the weather...

Above: A tram stop in Karlsruhe, Germany, crowded due to heavy rainfall. INIT

The increasing use of public transportation has compelled transport agencies worldwide to choose more efficient and economic resource planning. Recording and analysing the ridership demand has become a progressively more important issue, which is why ever more transport agencies and operators equip their light and urban rail fleets with Automatic Passenger Counting Systems (APCS).

Such passenger counting systems have become more and more popular, especially since manual counting means high recurring labour costs in documenting and reporting passenger numbers and the results are often not representative due to the short timeframe in which the counting occurs.

This article provides an overview of current passenger counting technology, the reasons why operators collect ridership data, and the latest developments in collecting, processing, and analysing such data.

In the early 1990s, the first electronic passenger counting systems appeared on the public transportation market. IRIS GmbH, a German-based company that produces and supplies optoelectronic sensors for various applications, has become the market leader in this field selling over 75 000 sensors worldwide.

In the pursuit of robust, accurate, and reliable technologies, IRIS GmbH has tested various sensors such as pyroelectric chips, infrared sensors, and optical stereo camera systems to determine which technology is reliable and (most importantly) affordable for the operator. There is no simple answer to this question as choosing the right sensor strongly depends on the task it is required for and its operating environment.

> "Recording windshield wiper activity of a tram, as well as date, time, location and passenger load, means weather-related deviations in ridership can now easily be detected."

The technology

Optical stereo camera sensors are well-suited for stationary passenger counting tasks. The detection of these cameras is based on two video cameras that are precisely aligned to create a three-dimensional picture (much in the same way as human eyes work). The left and the right camera record and compare each pixel, and from that information they can calculate in which direction a person or object is moving.

In order for this stereo vision technology to work correctly, there has to be a sufficient distance between the camera and the object. Since the doors of rail vehicles and buses are often not higher than two metres, these cameras have problems accurately detecting objects that are too close to their lenses. High temperatures, humidity and changing light conditions at stops often confuse the sensors which can result in decreased accuracy. This makes a 'one size, fits all' solution more difficult to implement due to the variety of operational parameters for light and urban rail systems worldwide.

Also, stereo cameras have a big disadvantage when operating in rough environments. This is especially true in bus and rail vehicles due to the strong and constant vibrations which can offset the cameras – any misalignment will make the accurate detection of movement impossible.

Infrared sensors are much more robust than stereo camera systems and that's why they have been the first choice in light rail vehicles and buses for the last two decades. These sensors permanently send out infrared light pulses which are reflected by the passengers and registered by the sensor. In order to disregard objects that should not be confused with passengers (such as backpacks, suitcases etc), high-sensitivity and high-resolution pyroelectric detection chips have been embedded to additionally detect thermal radiation emanating from passengers that should genuinely be counted. Combining these technologies sees the accuracy of such sensors reaching well above 95%.

With growing accuracy requirements, the passenger counting sensors have to accurately detect boarding and alighting passengers in tight crowds, and also be able to classify the passengers into adults and children.

As a logical consequence of higher expectations, IRIS GmbH has developed a sensor that is based on 'time of flight' technology. This so-called IRMA-MATRIX sensor uses an innovative and entirely new 'intelligent' detection method. Light pulses are sent out in quick succession using the invisible IR range; these pulses are reflected by objects and detected by the sensor. The distance to the object is then calculated by taking the period of time between transmission and reception of the light pulse. In this manner, the sensors know the height of the passengers, which allow them to differentiate between adults and children. The information of the three-dimensional image of the door space can also be used to distinguish between wheelchairs, bicycles and luggage, which all have their distinct silhouette.

Below: Come rain or shine the transport operator in Karlsruhe can schedule its services more effectively thanks to the latest weather-sensing technology. Neil Pulling

Unlike conventional technology, the MATRIX sensor does not need the door contact signal anymore, which has often been a source of malfunction in the past. The sensor is maintenance-free and can be subtly installed even in areas of limited access. Taking all factors into consideration it can be said that time of flight sensors are the most accurate and reliable technology for mobile passenger counting tasks. Some people may ask now, why is a high detection accuracy of such importance, and why do transport authorities and operators collect ridership data at all?

Why count passengers in the first place?

As an example, transport agencies in the United States receive substantial subsidies based on the number of passengers who use their services. To substantiate the need for funding to the government (NDT reporting), these transport agencies usually equip their entire fleets with APCS to benefit from these grants.

In Europe, on the other hand, we can often find several independent transit providers in one transport agency where revenue distribution is an important issue. In these cases, usually 15-20% of the fleet is equipped with passenger counting systems and the recorded data is used to extrapolate the results at the end of the year.

Apart from subsidies and revenue distribution, the ridership data is almost always used to measure the progress of the agency's ridership growth. Planners want to know how the provision of amenities, the increase or decrease of fares, schedule and route changes, or the relocation of resources affects the ridership in their transport network. In order to determine what effect has actually increased or decreased passenger numbers, an accurate ridership model is needed which is free from bias.

In other words, effects that influence the behaviour of the passengers should be taken into consideration to avoid the fallacy of composition. One effect that has a significant influence on the ridership behaviour is weather.

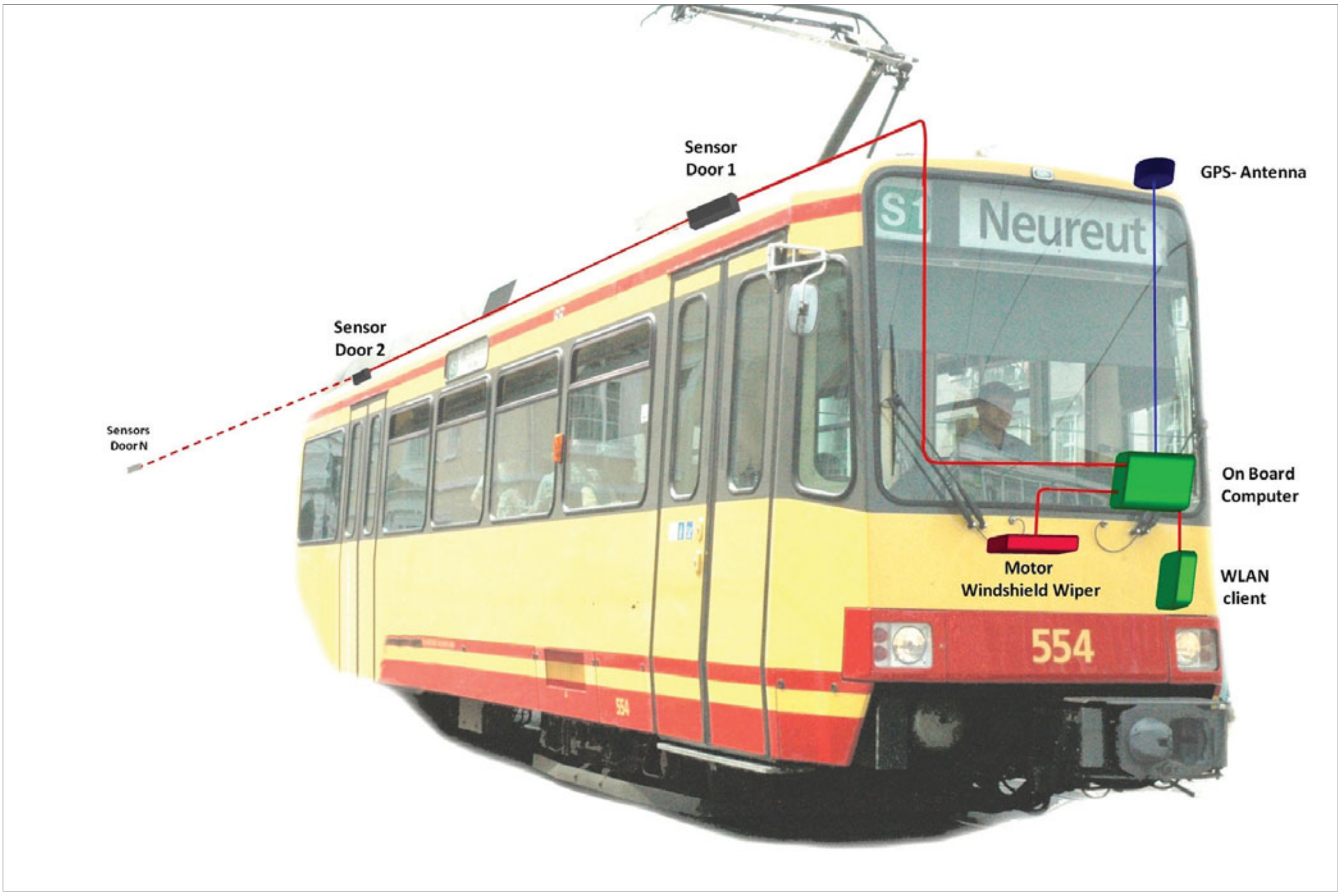
Weather impacts and the 'Third Cause Fallacy'

In many university cities, students use their bicycles to get to campus. On rainy days however, it can be observed that they switch from their bicycles to public transport. This results in a significant passenger fluctuation for the transport authority. Conversely, while the ridership usually increases on rainy weekdays, the opposite effect can be observed at weekends when people are not obliged to get to work or school. In adverse weather conditions, most people don't even walk to the bus or railway station – preferring to stay at home or take their cars.

To understand such complex ridership behaviour, let us take a look at the following example:

Suppose that ridership numbers in a statistics report indicate that occupancy of trams is 30% higher on Fridays in the month of June. We could now argue that more vehicle trips need to be planned in the future as people use public transport more frequently towards the weekend during summer time.

The fallacy in this situation is the assumption that Fridays – in the summertime – are correlated with a 30% higher occupancy level. The actual cause however has been heavy rain showers that coincidentally occurred on these Fridays. The third cause fallacy is a logical fallacy that asserts that A causes B when, in reality, B is caused by C; so in order to



The above diagram shows a typical APCS installation for one of Karlsruhe's Düwag trams. INIT

avoid such fallacies it is important to analyse the true cause before making the wrong assumptions.

"Everybody talks about the weather, but nobody does anything about it."

Mark Twain (1835-1910) US humourist, writer and lecturer)

Just because we cannot influence the weather, it does not mean that recording such data brings no extra benefits. Conventional APC systems record when, where, and how many passengers have boarded and alighted which vehicle. However, one important question that has a substantial impact on the occupancy level of public transport has been neglected in the past. That question is: *What was the weather like?*

INIT GmbH Karlsruhe/Germany has come up with an entirely new approach to recording ridership data and analysing these results in correlation to weather conditions. Since rain or snow can have a tremendous impact on ridership behaviour, INIT uses this additional information for analysis, planning and forecasting purposes.

Unlike conventional APC systems that simply record the date, time, location and passenger load, INIT's onboard computers additionally record the activity of the vehicles' windshield wipers. By checking the intensity of wiper activity (e.g. high, medium and low), conclusions can be drawn as to the intensity of the rainfall. Thus, no additional expensive rain sensors have to be installed and the technology can easily be retrofitted to the customer's existing fleet with a minimum of effort and invasion of the existing vehicle technology.

Utilising weather-related ridership data

With this new approach to recording the windshield wiper activity, weather-related deviations in ridership can easily be detected and used for many different purposes such as:

- **Ridership forecasting:** The weather-related statistics provide a realistic ridership model which can be used to predict the number of passengers who will be using public transportation based on the forecasted weather. If heavy rain showers are to be expected, transport authorities may send out additional vehicles on the affected lines well ahead of time to meet the expected demand.

  Or, depending on the recorded weather history, the planner might also decide to reduce or shift the fleet on certain routes if bad weather is expected. This new approach allows the planner to react proactively rather than taking dispositive actions when it is actually too late.
- **Revenue distribution:** Ridership on both rainy and dry days can now be automatically considered in the calculation of revenue distribution. So before the available data is being extrapolated it will be classified (just like weekdays and weekends) to avoid bias and enhance the arithmetic of the calculation.
- **Monitoring of service improvements:** Amenities, such as new shelters in more rural or suburban areas, are likely to increase ridership comfort. Therefore, the effects of such improvements may now be accurately quantified.
- **On-time performance:** Furthermore, the recorded weather data may also be used to analyse the impact of bad weather conditions like rain, ice, and snow on the on-time performance of a fleet.

Bad weather often results in congested traffic, which may again have a higher impact on trams and buses. Furthermore, it has been observed that the dwell time at stations is considerably impacted by rain; schedules can therefore be optimised to the extent that they take such extended dwell times into consideration.

Telematic systems that utilise weather-related data are still in their early stages, and although weather conditions influence ridership numbers, very little attention has been given to this subject.

INIT (Innovations in Transportation) has taken the first step in incorporating such data on a commercial basis by simply recording the windshield wiper activity of the vehicles and analysing this data with statistical modelling. This way transport authorities and operators can easily retrofit or expand their existing fleet into 'rolling weather stations' and improve their fleet management. TAUT

Georg König graduated from the school of business at Southern Connecticut State University (USA) in 1997. After working as a consultant for six years he has managed several R&D projects in the field of textile machine construction. Georg joined INIT in 2010, where he is responsible for Automatic Passenger Counting Systems.