



Technical Article

Human Machine Interface Systems for *Passenger Access in Rail Applications*

Although doors and door controls make up only 2-3% of the cost of passenger rail cars, it is estimated that they are responsible for as much as 25% of the maintenance costs. In Europe and Asia, localized passenger door controls are the norm; in North America, operator/ conductor controlled doors are much more common, although passenger controls are commonly incorporated into door systems on light rail (tram) type vehicles and some subway cars. The majority of new light rail systems in North America have passenger-actuated doors, which increase comfort inside the car and may reduce wear and tear on the door system. However, at busy stations, where the use of all doors is generally required, operators tend to override passenger control actuation and open and close all doors at once, avoiding any last minute opening and closing by passengers.

The primary traditional justifications for localized passenger controls almost always involve HVAC/climate benefits. When passengers have control of the doors, the cars tend to retain more heat or cooling since passengers can close doors faster, when no one is entering the car. There can also be an impact on dwell time. On some European lines where doors don't automatically open if not activated by passengers, waiting times have been reduced. Whether localized passenger door controls affect Mean-Time-Between-Failure (MTBF) or Mean-Time-To-Failure (MTTF) currently seems to be unknown. As railway lines investigate semi-automatic, driverless, and unattended train operations, the responsibility for door control even in North America may come to rest squarely on the passengers' shoulders.

Regardless of who is controlling the doors, the critical elements include safety, ease-of-operation, integration with existing control systems, accessibility for all passengers, and reduction of the potential for human error. In this article, we will discuss the latest trends and requirements in passenger access as they relate to door systems, with a mention of other passenger access issues related to toilet compartments and passenger alert systems.

Door control systems on passenger rail cars have developed beyond simple open and close buttons. These control systems provide the most common area for passenger interaction with the rail car. The design of passenger access systems for rail involves all the aspects of a Human Machine Interface (HMI) System:

The task of an HMI System is to make the function of a technology self-evident to the user. *In passenger access applications, the HMI has to be intuitive, easy to see and understand, and clear in its feedback to the passenger.*

“Trends in HMI Systems for passenger access include better illuminated symbols and indicators, the addition of simple and complex tones to provide audible feedback, sealed HMI components, and “secret-until-lit” controls.”



Series 57 addresses the critical elements for passenger access include safety, ease-of-operation, and accessibility for all passengers.

- Careful consideration of human factors.
- Ergonomic criteria, including Americans with Disabilities Act (ADA) requirements.
- Interoperability throughout a rail fleet.
- Clear and simple presentation of critical data.
- Clear and consistent feedback to the passenger, both audible and visual.

Integration of industry and federal guidelines and best practices. Human Machine Interface (HMI) Systems provide the controls by which a user operates a machine, system, or instrument. For passenger access in a rail car, the system to be operated is usually a door control. Door controls in North America are usually automatically controlled and operate all at once, triggered from a master door controller found in the operator compartment. As stated previously, local passenger door control is primarily found in light rail or streetcar installations. According to the latest APTA Standards Development Program Rail Standard (APTA SS-M-18-10, Approved February 11, 2011), passenger access for powered exterior side doors on passenger cars incorporates the minimum design requirements necessary for doors that provide:

- Entrance and exit for passenger boarding and detraining.
- Emergency egress/access path.

The standard was developed with input from transit operating/planning agencies, manufacturers, consultants, engineers, and general interest groups. Designing and integrating HMI control systems is a task often undertaken by specialized suppliers to

complement the core capabilities of end-product manufacturers, in this instance, rail car manufacturers. Some manufacturers use an HMI supplier as an extension of their design team, a knowledgeable partner who provides added design capacity and fast turnaround.

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Trends in HMI Systems for passenger access

Trends in HMI Systems for passenger access include better illuminated symbols and indicators, the addition of simple and complex tones to provide audible feedback, sealed HMI components, and “secret-until-lit” controls. In addition, programmable doors are becoming more popular. Here, the amount of time for the door to close, the amount of force acting on the door, and the amount of force necessary for emergency or manual release, are adjustable through a programming interface within the door control system. HMI Systems that offer reliable, intuitive, and ergonomic performance are essential to both the passenger and rail crew. In the United States, the ADA regulations require that controls be accessible for passengers with disabilities, utilizing the overall simple functionality and ease-of-use

Control systems need to interface with other on-board equipment. *Choosing the right communication interfaces is a key part of the design of the HMI System.*

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HMI Systems for passenger access include normal passenger boarding and detrainning, as well as emergency egress. Above: Series 57 emergency-call.

criteria applicable to public access applications. Passenger applications often use audible feedback, such as voice/sound indicators. Passenger HMI controls can also include override systems, and emergency-call equipment prompted by audible, visual, and hidden indicators, and programmable acoustic warning signals. In addition, the audible alert is sometimes used to help visually impaired passengers locate door actuation pushbuttons or the doorway opening. A unique tone is emitted that maintains a sound level in the approximate range of 2 – 5 dB above the ambient sound level. This allows the tone to stand-out from the noise commonly found in the environment.

In Europe, the European Technical Specification for Interoperability for Persons with Reduced Mobility (TSI-PRM) makes it easier for disabled passenger to use trains by setting standards for passenger access and on-board information. It applies to all heavy rail (train) vehicles on the major lines of the mainline rail system in Europe. TSI-PRM sets standards for audible sound pressure levels of door opening alarms, the intensity of lighting within a car and at the station, height of door access controls, even the amount of force required to activate a switch. In addition to setting the requirements for door controls, it also stipulates standards for on-board toilet facilities, including controls which allow access to the restroom, door locking, toilet flushing, and washing, all must be compliant.

Functions that must be considered under TSI-PRM in upgrades, include:

- Seats, back grab handles on seats.

- Wheelchair spaces.
- Exterior and interior doors.
- Toilets.
- Clear-ways/aisles.
- Information displays.
- Height changes for controls.
- Handrails.

Standard HMI components for passenger use could include:

- LED illuminated pushbutton switches and indicators.
- Emergency stops.
- Keylocks, levers, and rotary switches.
- Emergency passenger alert functions.
- Switch systems that incorporate all the necessary information required for a passenger, including pushbutton, indicator, and feedback with visible and audible notification and easy location with an ambient responsive finding signal.
- Interlocks.
- Keypads and keyboards.
- Programmable audible alerts.
- Responsive audible alerts.

Controls must also be durable and as “mistake-proof” as possible. In addition, control systems need to interface with other on-board equipment. Choosing the right communication interfaces is a key part of the design of the HMI System, whether that includes hard-wiring, bus systems, or even wireless communications.

Application considerations

HMI Systems for rail consider passenger use from every angle. In addition to meeting regulations for ADA and Rail Vehicle Accessibility, HMI

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“In addition to passenger door control, HMIS for doors in on-board public restrooms must be reliable, visible, and easily operated.”



Most passenger rail applications demand a minimum IP 67 component standard. Above: Series 82 IP67 pushbuttons.

Systems also consider everything from environmental demands to aesthetic appeal.

To address potential environmental concerns, stainless steel and durable polymer-based products are often given top consideration for reliable operation under demanding conditions. Where required, control products fabricated from these materials offer protection up to IP 67, as well as resistance to heat, shock, vibration, and vandalism. They are designed for minimal maintenance and long-term use and abuse. They deliver a long life-cycle at a great cost benefit – very appealing to transportation companies.

The International/Ingress Protection, or IP rating system, is widely used throughout Europe and describes the degree of protection as defined by the International Electrical Commission (IEC) standard 60529. The degree of protection as defined by the IEC is used to describe:

- Protection offered to people against hazardous parts inside and enclosure;
- Protection of equipment inside the enclosure against the intrusion of solids;
- Protection of equipment inside the enclosure against the ingress of liquids.

HMI devices are defined as an enclosure by the IEC. The rating proves the device has been tested according to international standards, providing a more detailed measure than generic terms like “waterproof.” In an IP number, for example IP 67, the first number is a measure of how well the enclosure can prevent an

invasion by solids – 6 is dust tight. The second number represents the measurement of protection against liquids at various pressures – 7 indicates protection against immersion beyond one meter. Most passenger rail applications demand a minimum IP 67 for external HMI components, due to the risk of immersion.

Illuminated pushbuttons are often found in passenger rail door applications. Featuring a bright front bezel, LED halo illumination, and a large touch surface that can be supplied with Braille text for the partially sighted, the illumination immediately focuses user attention on the control. These pushbuttons are also immune to the harshest graffiti cleaners available. In safety and security applications, crew key switches protect against unauthorized access and act as additional safety controls. Each switch actuator is comprised of a unique rotor shape identified by the transit authority. These special purpose keylock switches are ideal for heavy, commuter, and light rail environments and can be used in flush-mount designs for increased vandalism resistance.

In addition to passenger door control, HMIS for doors in on-board public restrooms must be reliable, visible, and easily operated. Wheelchair access requires that pushbuttons are fitted to certain heights and operable by palm. In passenger toilet compart-

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APTA standards cover door and system requirements including HMIS design.

ments, there are several functions that must be easily defined and accessible, in addition to toilet control. These include multiple passenger emergency positions for signalling an emergency to the crew, door lock/door open, lavatory controls for water, soap dispenser, hand dryer, and others.

Balancing aesthetic appeal and standards

Aesthetic considerations are a powerful factor, since these systems are often the primary interface between the transit entity and the rail public. Controls that combine aesthetically pleasing design with ease-of-use create a good impression and actually make operation more foolproof for the passenger.

In rail, great HMI design begins with understanding the user. Often, there may be a defined standard that captures the user's best interests and highlights best practices. These include federal human engineering standards, such as those set by the ADA, the American Public Transportation Association (APTA), the Department of Transportation Federal Railroad Administration, the International Railway Industry Standard (IRIS); and HMI guidelines from industry organizations, such as the American National Standards Institute (ANSI), IEEE, ISO, and others. APTA standards cover the requirements for doors and door systems, including HMI design.

The door system includes a door control station to provide control of the powered side doors for passenger entry and exit, or other doors on the rail car with connection via trainline control systems to other cars. The control station requires crew key

access to prevent unauthorized access. The key remains captured during operation; if removed, the doors are prohibited from opening and closing. Each door is provided with a service-proven obstruction detection feature. The door control is arranged so that any obstruction is sensed throughout the closing cycle until the door is fully closed and locked. Recycling of the open/close sequence continues as long as the obstruction is detected.

Door operators and controls are considered safety critical functions. An emergency release actuation device is provided immediately adjacent to the door opening on both interior and exterior. The actuation device is covered by a clearly labelled, breakable or hinged panel, to reduce nuisance operations. The device must be readily accessible, without the use of tools or other implements, as per 49 CFR Part 238, (Rail) Passenger Equipment Safety Standards. Visible and audible door status indicators are part of the HMI System and are incorporated into the door control station to display the open or closed status of the door. It is also common for these door motion status indicators to be located overhead. Door-out-of-service (DOOS) indication is also required and is usually a blind front, hidden until lit, indicator that displays the DOOS status by illuminating the text or door symbol with a red "X" through

It is also important to be familiar with the Buy America Act that encourages and rewards using United States-serviced manufacturing.

Doors, door controls, and HMI Systems for door control are covered under the Buy America Act.

“Buy America requirements aid in encouraging development of domestic manufacturing locations. For a component to be considered of domestic origin, more than 60% of the subcomponents of that component must be of domestic origin.”



Wide angle Series 56 conical warning indicators are visible from far away.

the symbol.

Buy America

It is also important to be familiar with the Buy America Act that encourages and rewards using United States-serviced manufacturing. The Passenger Rail Investment and Improvement Act of 2008 (PRIIA) authorized the appropriation of funds to establish several new passenger rail grant programs, including capital investment to support intercity passenger rail service and high-speed corridor development, as well as eliminate roadway congestion. The Federal Railroad Administration (FRA) consolidated these and other related programs into the High-Speed Intercity Passenger Rail (HSIPR) program, as funded through the American Recovery and Reinvestment Act of 2009. The HSIPR program implements the 2009 “Vision for High-Speed Rail in America” and includes goals to bolster American passenger rail expertise and resources.

Buy America requirements aid in encouraging development of domestic manufacturing locations. Buy America applies to all PRIIA authorized spending and requires that all steel, iron, and manufactured goods used for stimulus-backed public works projects be produced in America. A component is any article, material, or supply, whether manufactured or un-manufactured, that is directly incorporated into an end product at the final assembly. A component is considered to be manufactured if there are sufficient activities taking place to advance the value or improve the condition of the subcomponents of that component. For a component to be considered of domestic origin, more than 60% of the subcomponents of that component must be of

domestic origin. If this is not the case, a waiver must be obtained to be used in a public works project. A waiver can be obtained if:

- Quality or quantity from United States based suppliers is insufficient;
- Cost of US-produced goods make the total project cost (not just the raw material costs) more than 25% above the cost if foreign goods are used;
- Previously existing trade agreements require interpretation.

Doors, door controls, and HMI Systems for door control are covered under the Buy America Act. Similar commercial stimulus programs exist in all major manufacturing regions in the world with the same goals as the Buy America program.

According to data from the independent monitor Global Trade Alert (GTA), there were around 100 new discriminatory measures introduced per quarter in 2009. Ranked according to the absolute number of discriminatory measures imposed, the number of sectors affected by those measures, and the number of trading partners affected, the EU-27 topped the global ranking. However, this ranking needs to be put into context. The EU-27 also ranks second behind China as a target of other governments protectionist measures. The EU acts as a determined defender of its global trade

The position of components, their surface area, legend size and colour, emergency-stops, switch guards plus ergonomics are all critical factors. *The goal is optimal usability, efficiency, and safety.*

“The key to an effective HMI System for any passenger rail application is consistent and predictable performance with time-proven controls that are familiar and intuitive to all passengers. Controls need to be clear and easy to understand and use in order to reduce the risk of human error.”



Feedback can be visual, auditory, tactile, or any combination necessary for the application.

interests. Canada, while not as active as the EU, still defended its national interests with vigour.

Defining the operational/functional requirements

The key to an effective HMI System for any passenger rail application is consistent and predictable performance with time-proven controls that are familiar and intuitive to all passengers. Controls need to be clear and easy to understand and use in order to reduce the risk of human error.

General functionality

How many functions will be controlled by this interface? Typically, these controls have very few, specific functions. What kind of visual, auditory, or tactile feedback will best serve the passenger in the performance of the defined functions?

Degree of input complexity

Input can be as simple as an on/off, emergency stop.

Operator feedback

Feedback is critical to operator effectiveness and efficiency. Feedback can be visual, auditory, tactile, or any combination necessary for the application. In some cases, feedback provides confirmation of an action, while in others it adds to the functionality. Meeting industry best practices is important in the placement of components, the component's surface area, legend size and colour, emergency stop consideration, protective switch guards and shields, plus other ergonomic factors. The goal is optimal usability, efficiency, and safety.

Environmental considerations

The application environment – encompassing both physical location and vertical industry environment – determines HMI System durability requirements. Anti-vandalism considerations are part of the rail environment and must be considered.

Life-cycle durability

Not only should the HMI System be rugged enough to withstand heavy use, but it should also last for the duration of the equipment life-cycle. Durability and reliability are also key for passenger cars with very long service lives.

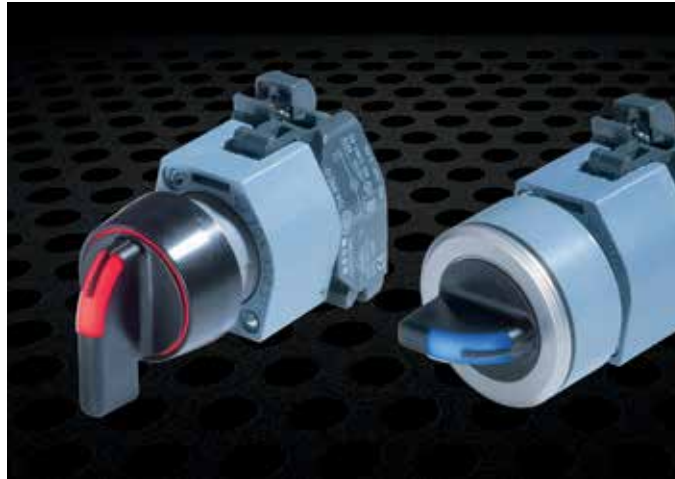
Regulatory/standards

Thorough knowledge of technical ergonomic, design, and manufacturing standards is fundamental to HMI System design. As part of the regulations specific to passenger access, the following audio components are required:

- Audible warning device, as well as visible LED signal light;
- Location at each side of the door to alert passengers of closing doors;
- Audible and visible signals shall activate independently for an adjustable period of 1 to 5 seconds before door close; initially set at 2.5 secs;
- Signal shall be rated for 30 to 95 volts DC with adjustable output of 75 to 95 dB(A);
- Audible signal must be located at its affected individual door as a steering

The operator in passenger access will be a passive/intuitive user. Commands/ functions should be simple with an easy-to-comprehend interface.

“Once you have defined HMI functionality, you are ready to investigate control technologies. Each technology has advantages and disadvantages related to the HMI System, equipment, and application. Many of these technologies are of more importance to operators than passengers.”



Rotary-switch and keylock technologies serve best when the application requires position indicators.

aid for the blind.

Define the operator

Know your operator – the key to a successful HMI System implementation requires a well-grounded definition and understanding of the operators. The operator in passenger access will be a passive/intuitive user. Commands/ functions should be simple with an easy-to-comprehend interface. For this type of user, repeatability is also important – information and actions should appear consistently from use to use.

Panel layout

The panel layout should be designed to provide the operator functional groups of related information in a predictable and consistent manner. The panel will incorporate:

- Electromechanical assembly;
- Ergonomic design;
- Vandal resistant and durable construction;
- LED illumination.

HMI Component selection

Typical HMI components for passenger access applications can include the following:

- For “Door Open” and “Door Close” symbols:
 - LED backlit switches
 - Consistent actuation force of 6N or 12N
 - 16mm symbols
 - Environmentally tough: -45°C to +80 C°

- IP 67/65 front/rear protection
- Large actuation area
- For ADA symbols:
 - LED backlit switches
 - Wide voltage input
 - Wide voltage tolerance ±30%
 - Environmentally tough: -45°C to +80°C
- IP 67/65 front/rear protection
- TSI PRM Sound module
 - Audible alert
 - Consistent appearance
 - Up to five different tones
 - Complex tones
 - Pressure level to 90 dB
 - IP 69K front protection
 - IP 67 rear protection
 - Volume adjust box control

How Do You Choose the Best Control Technologies?

Once you have defined HMI functionality, you are ready to investigate control technologies. Each technology has advantages and disadvantages related to the HMI System, equipment, and application. Many of these technologies are of more importance to operators than passengers.

Switches (Pushbutton, rocker, slide, keylock, rotary, etc.)

Pushbutton switches allow the option of illumination to indicate open/close switch status when a quick visual indication is desired. Rotary-switch and keylock technologies serve best when the application requires position indicators. Keylocks provide an additional layer of security to the application. Rotary

Door operators and controls are considered to be safety critical functions. Exposed wire bundles or flexible conduit are typically not allowed.

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“Measures to assure safety and usability offer a delicate balance between the ability to instantly stop a system in an emergency and protecting against accidental stoppage that might cause an emergency.”



Series 57: the ideal product range for all public transport passenger access requirements.

switches also can be used for an application requiring multiple positions. Slide switches are the technology of choice when ease-of-use and low-cost switching is desirable – commonly found on notebook cases and hand-held on/off functionality.

Short travel technologies (Conductive rubber, membrane, keyboard, keypad, etc.)

Short travel technology can include cost effective, conductive rubber keys in a typical keyboard, dome keys under an overlay, or a multi-layer membrane. Display technologies (LCD, Active Matrix, OLED, FED, Plasma, etc.) Display technology choices are dictated by the HMI System environment and its degree of ambient illumination, as well as by colour requirements. Active matrix LCD technologies are commonly used for colour functionality, while legacy LCD technology is used in applications where monochromatic feedback is sufficient. OLEDs, organic (carbon-based) light-emitting diodes, can currently support smaller displays.

Passenger Alert Applications

Measures to assure safety and usability offer a delicate balance between the ability to instantly stop a system in an emergency and protecting against accidental stoppage that might cause an emergency. Passenger alert applications require HMI Systems for doors within the passenger compartment, as well as in any on-board restrooms. Applications may include:

- Unique door identification markings;
- Audible and visual door closing alerts;
- Distinct and consistent tones for different alerts (door closing

tone is distinct from emergency tone);

- Consistent placement of door controls and emergency buttons/controls;
- Manual interior and exterior door emergency release mechanism at each door with a clearly labelled, breakable or hinged cover for access to the actuation device;
- Labelling consistency for emergency signage that complies with APTAS SSPS- 002-98 and 49 CFR parts 238 and 239;
- Door cut-out switch.

Connecting/Communicating with an HMI System

Typically, communication/connection on rolling stock is hard wired. Hard-wired systems require no special tools and are simple, visible, and easy to understand, especially where the HMI interface controls a single operation, for example, power distribution.

Door operators and controls are considered to be safety critical functions and are designed to operate at a nominal voltage of 24, 37.5, or 74 V with + - 30% tolerance over a voltage range of 55 VDC to 80 VDC at the door control panel. All door wiring is installed in rigid conduit. Exposed wire bundles or flexible conduit are typically not allowed. All electrical and mechanical components of the door system are fully accessible for easy maintenance, troubleshooting, repair, and adjustment.

The effectiveness of the HMI System—and consequent effectiveness of its use—depends upon an exacting design process that incorporates all technical, ergonomic, and communication requirements. *Work with a supplier who understands the market fully.*

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The design and installation of doors and door control systems must comply with the requirements of 49 CFR Parts 27, 37, 38, and 238, as well as APTA recommended practice RP-C&S-012-99. All parts of the door and door control systems are subjected to a Failure Mode and Effects Analysis (FMEA) for hardware, as well as fault tree analysis for circuit design. On some cars in Europe, door communications/connectivity is accomplished using the CAN-Open bus interfacing by means of digital I/Os. The doors can be configured for opening and closing by input parameters from a train controller. Intermediate sealed connectors are typically used to connect with the rail car's wiring harnesses. This allows for easy repair and replacement of passenger use controls that can maximize revenue service time. Popular sealed connectors are offered by Tyco and Deutsch. The intermediate connectors make maintenance and replacement easy.

U.S. and Industry Standards by Application

ISO (International Standards Organization): 9000, specifically for railway EN 5155 develops standards for electronics on rail way passenger vehicles.

The Federal Railroad Administration (FRA, under the U.S. Department of Transportation) is responsible for defining standards covering safety issues.

ASTM (under ANSI) specifies testing procedures in transportation; a range of ASTM standards provide methodology and performance specifications for testing FRA regulations flammability testing.

49 CFR Appendix B to Part 238 – Test Methods and Performance Criteria for the Flammability and Smoke Emission Characteristics of Materials Used in Passenger Cars and Locomotive Cabs <http://cfr.vlex.com/vid/238-flammability-smoke-locomotive-cabs-19946592##ixzz-0n5YL4A8X>.

Americans with Disabilities Act (ADA)

American National Standards Institute (ANSI)
Institute of Electrical and Electronics Engineers (IEEE)

IRIS (International Railway Industry Standard) Rev. 02; ensures products meet globally recognised quality levels.

Summary

The effectiveness of the HMI System — and consequent effectiveness of its use — depends upon an exacting design process that incorporates all technical, ergonomic, and communication requirements. For passenger access in rail applications, working with an experienced HMI Systems supplier can ensure that the system meets all standards and provides the successful and safe operation of passenger access and exit doors on rail cars. Working with a supplier that understands the applications, environment, user of the equipment, and the nature of their usage is critical to the successful implementation of an effective and aesthetic pleasing HMI System.