Overview

Robotic delivery vehicles, also known as automated guided vehicles (AGVs) or self-guided vehicles (SGVs), have been widely used in material handling for decades. More recently, these mobile robots are in higher demand in hospitals as a result of changing demographic and healthcare cost-control trends. For healthcare applications, these automated systems are designed specifically for bulk material handling; transporting food/soiled dishes, clean/dirty linens, trash/biohazard/recyclable waste and all types of non-urgent supplies, in carts weighing up to 1,300 pounds. Operational efficiencies are gained by automating these deliveries, allowing redeployment of human resources. A number of issues can impact the successful implementation of AGV Systems in new hospital construction or major hospital expansion. This white paper outlines a dozen key design considerations for architects and planners to ensure their projects are robot-friendly.
Definitions

AGV Systems are distinguished from Autonomous Mobile Robots (AMRs) by the routes they travel (back of house), their heavier payloads and how their robot fleets are managed. AGV systems automatically pick up carts (up to 1,300 lbs.) from specific locations (with detents) and transport them along defined paths in designated corridors and elevators. The orders to move carts, vehicles and elevators are closely coordinated by the TransCar Manager Server.

AMRs, by contrast, carry smaller payloads (up to 100 lbs), travel in patient and user department areas and travel freely in corridors to get around obstacles. They often operate by themselves or in small numbers with minimal coordination for negotiating doors and elevators. If AMRs are taxi cabs, AGVs are freight trains. AMRs typically do not require as much advance planning for space and elevator configuration in the facility design as AGVs do.

AGV = Automated Guided Vehicle
P&D = Pickup and Delivery (also referred to as Send and Receive)
TransCar Manager = Server and client computers and software managing the fleet. Interfaces with elevators, doors, battery chargers, sensors, indicators, user input terminals, etc.

1. Corridor Space

Consult with the Authority Having Jurisdiction (AHJ—i.e., local fire marshal) early in the project to educate them on your intention to use robots and to determine what is required for egress space in robot corridors. Some AHJs may view the robot/automated guided vehicles as a permanent obstruction and therefore require egress space for a given corridor be added to the robot’s travel space. It is usually beneficial to separate patient and visitor traffic flows from the “back-of-house” material handling highways, but is not always necessary with proper corridor sizes.

The ANSI/ITSDF B56.5-2012 Safety Standard for driverless, Automatic Guided Industrial Vehicles and Automated Functions of Manned Industrial Vehicles states: “A minimum clearance of 0.5 m (19.7 inches) shall be maintained between obstructions and vehicles (including loads). All other areas having reduced clearance shall be considered hazard zones or restricted areas and be clearly marked by signs, stripes, lights, or other designations.”

An AGV’s travel envelope with a cart is nominally 34 inches wide during straight travel. Including the ANSI clearance space, a minimum corridor width could be as little as 74 inches for a single lane of traffic. Since carts have to move in both directions, two lanes of traffic are normally required in the same corridor. Using the ANSI standard clearance space between passing vehicles in opposite directions, the minimum corridor width is 127 inches (10’-7”). With proper markings and 12 inches between passing vehicles, robot corridors could be as narrow as 10 feet.

The above dimensions based on the ANSI standard, are exclusive of the Fire Marshal’s egress requirements. The diagram (right) illustrates the 10 foot, 7 inch corridor example. This results in an egress lane of 6’-1 1/2” from the side of one vehicle to the furthest wall. Vehicles traveling in opposite directions can be controlled to stop (during a fire alarm for example) so they are not directly across from one another, or even to travel to locations off the main egress. 

Corridor Width Example
routes during a fire alarm. The Fire Marshal may want to see more space for AGVs, so it is important to discuss the issue with them early in the design phase, and certainly before setting the corridor widths or elevator cores in concrete.

Vehicles require additional space when turning, so ideally the corridor is wider near busy intersections. Otherwise, the travel lanes will need to merge closer to each other and only one vehicle will be able to pass through the intersection at a time, which reduces potential throughput capacity.

Consult with robot vendors during the sizing and positioning of intersections and the AGV cart pick-up and delivery (P&D) areas (especially at the AGV elevator vestibules and user departments). Space planning layouts done without knowledge of required vehicle maneuvering space usually end up compromising the speed of the P&D function (system throughput) and inevitably end up losing usable space that could be allocated to adjacent rooms. Locating the user department P&D stations immediately off the corridor allows the vehicles to maneuver in corridor space, as opposed to taking up space inside the user departments.

The robotic vehicles also require space adjacent to corridors or P&D areas for parking and opportunity battery charging. Every vehicle requires a parking space when there is no transport activity.

For additional information on egress space, elevator and fire door operation please follow this link: AGV operation during fire alarms.

2. Floors and Floor Coverings

Floors should be capable of supporting the robots at 725 pounds per square inch (350 N/cm²) and level to the following tolerances: 3/16" (5 mm) per three feet (1 m) in AGV travel areas, 1/8" (3 mm) per three feet (1 m) in AGV charging locations.

The floor and floor coverings should adequately withstand continuous and repeated travel of motorized vehicles with a single motorized polyurethane driving and steering wheel with wheel loading up to 1,200 lbs (550 Kg). Expansion joint transitions should not exceed a horizontal gap of 5/8" (15 mm) and vertical misalignment of 1/8" (3 mm).

Floor coverings, sealers or coatings must have anti-static/conductive properties with an earth resistance between 10 K-ohms and 1 M-ohms (measured according to DIN). Abrasion of the floor covering should not exceed 6.7 inch³ with a load of 5 N resistant. Floor covering shall be a different color within the corridors to visually separate vehicle’s travel space (see ANSI Safety Standard) and clearance space.

The friction coefficient between the vehicles' wheels, made of Vulcolan (polyurethane) and any floor surface under any condition (dirt, moisture after cleaning, etc.) should be > 0.5. Ceramic tiles must be installed evenly, with joints between tiles a maximum 1/4" (5 mm) wide and filled flush. Maximum ramp slope should be 7% (4°, or 1:14). Radii for transitioning onto and off of each ramp shall be a minimum 3.3’ (1m). Length, slope and transition design details for all ramps should be submitted to the AGV System contractor for review and approval. The robot's payload capacity may have to be de-rated depending on the ramp's slope.

3. Carts

To derive the number of cart movements, it is useful to know the volume and capacity of the carts. Cart footprint is 32" wide by 54" long. Cart heights can vary. The capacity of the robot is a maximum of 1,300 lbs, however most carts weigh less since manual movement of 1,300-lb carts is difficult. The cart’s tare weight should be subtracted from the robot capacity to get net capacity. The size, space and features underneath the cart have to be specific for the robot to interface properly. Thus, it is best to obtain specifications directly from the manufacturer. For example, self-centering
swivel-casters and magnets on the cart improve the handling during automatic pick-up and delivery operations. See Optional Equipment/Functionality section on automatic cart washers for cart styles that can reduce the number of cart movements.

4. Elevators

Vertical transport via cart lift may not require a full-fledged elevator—depending on state code. Since soiled laundry and trash are undesirable sights on personnel and public elevators, and cart transport frequency will likely demand full-time use, it is best to dedicate vertical lift(s) to AGV Systems for material transport between the service levels of the hospital and the nursing units they serve. The quantity of lifts required depends on their frequency of use, and it is entirely possible that more than one lift will be required. Frequency estimates can be determined from a 24-hour cart movement or throughput matrix (see below).

Ideal lift requirements include:
> 2,500 lbs. minimum cabin capacity per vehicle
> "C-1" load rating
> 40” minimum clear door opening
> 60” minimum cabin width inside
> 96” minimum cabin depth
> Maximum gap between lift and floor thresholds = 1\(\frac{1}{8}\)
> Leveling tolerance ± 0.2”

We recommend including a requirement in the elevator control system specification for an interface to an AGV System so the elevator supplier includes this functionality at bid time and does not involve a change order later on.

Planners should analyze where to locate the AGV elevators. If cart movement traffic is higher than one elevator can accommodate, it might be better to have individual elevators serving multiple nursing units rather than two or more in one location. Doing this may significantly reduce the horizontal cart movements across the patient floors, as well as reducing the associated noise, congestion and operational expenses.

Elevators and the associated cart P&D vestibules are normally dedicated to AGV movements. Doing this removes undesirable cart traffic from the service elevators used to transport staff and patient beds. It allows higher throughput via more efficient AGV operation and avoids personnel from being locked out during AGV movements on the elevator.

It may be desirable for both sides of the elevators to open up, with one side for soiled cart P&D, and one side for clean cart P&D. If space allows, a drive-around path further enhances AGV System throughput by allowing the AGV to release the elevator while it delivers one cart and drives around to pick up another. The elevators themselves, however, need not be dedicated to clean and soiled functions (except in systems dedicated to move case carts). Dedicating the elevators for clean and soiled movements will as much as double the number of elevator movements required to move the same number of carts—since the vehicles are forced to make an empty deadhead trip for every trip with a cart. Additional vehicles would also be required. Properly designed carts and material containers can serve as the primary containment of soiled materials. Moving them on dedicated AGV elevators keeps them away from patient and staff elevators.

For additional information on egress space, elevator and fire door operation please follow this link: AGV operation during fire alarms.

A detailed control interface specification is available from Swisslog, which defines the signals and timing sequence between the robot and elevator systems. Contact Swisslog at healthcare.us@swisslog.com.
5. Send and Receive Stations

On the patient floors, interventional floors and in each of the main support-areas, cart Send and Receive Stations (also known as pick-up and delivery (P&D) stations) consist of cart positions for the robots to pick-up from and deliver to. The Send Stations require a set of guides or detents mounted to the floor to assist with proper user positioning of the cart for pick-up. The Send and Receive Stations require a sensor mounted in the ceiling to detect presence of a cart underneath. Quantity and location of these stations is dependent on the throughput matrix (see below), human response time and the maneuvering space for the vehicle. Check with the manufacturer to determine the space requirements in a proper layout.

After positioning a cart in a Send Station, the destination is entered on a touchscreen dispatch terminal mounted on a nearby wall. The cart destination can be one of multiple locations (as in the case of a support department such as dietary, pharmacy, materials management etc.). Dispatch terminals may not be required when cart destinations can be determined automatically. For example on a patient or interventional floor, the overhead cart sensor initiates the pick-up and the vehicle reads a bar code or RFID tag on the cart to obtain the destination.

6. Automatic Doors and Fire Doors

Each doorway the vehicles travel through must either be held open by electromagnet or motorized. The manufacturer's control interface specification will describe the required signal interaction so that once a vehicle starts through the doorway, the operating mechanism (EM or MO) will hold the doors open until the vehicle has passed completely through the door's swing radius (delayed closing). UPS power is needed to hold the door open during vehicle passage, even during a power outage.

A signal from the door control is required to tell the TransCar Manager that the doors are completely open and ready for vehicle passage. All smoke, heat and fire detection is a function of the fire control system and a delayed closing is needed when a vehicle is in the doorway at time of alarm.

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7. Power Circuits

Fused disconnects and three-phase power (480/3/60 – 20 amp service) are required at each battery charger location and single-phase power (115/1/60 – 20 amp service) to each star distributor (network switch), I/O controller, dispatch terminal, motorized door, and the TransCar Manager computers. All AGV System equipment power should be backed up with emergency power and all computers backed up with UPS power.
8. Clean and Soiled P&D Rooms

Most materials are transported between the support departments, receiving or dock and the nursing units, so cart queuing near the patient areas is best provided in clean and soiled P&D rooms. These rooms are actually lobbies connected to the AGV elevators, adjacent to the general circulation of the nursing unit and accessible via doorway. The door should be motorized if carts are manually moved outside this room. The clean holding room may have a lockable door with controlled access for protection of materials being delivered, while the soiled room may be open for nursing/housekeeping personnel to deposit materials in soiled carts. The location of the door needs to be coordinated so as not to interfere with vehicle travel envelope in the lobby.

For floor levels with a lot of cart deliveries, it is best to have a travel passageway for vehicles to travel from the clean side to the soiled side on the floor, so vehicles can release the elevator while they deliver a clean cart and drive around the core (through a motorized door) to pick up a soiled cart.

The quantity of clean and soiled cart P&D positions in each room is dependent on the system throughput matrix, the human response time (cart delivery notification systems can help reduce this response time) and mode of operation (if carts are relocated after delivery or remain in place for loading). Rooms on each floor can be different sizes to accommodate varying numbers of cart P&D locations, but are often identical from one patient floor to another.

For floors with low cart movement activity, a minimum of one pick-up position and one cart delivery position should be provided in each of the clean and soiled areas. In busier systems, two or three of each may be necessary. Ideally, large lobby rooms would allow the soiled carts to stay in the delivery position until full and pick-up is necessary (no material handling is the best kind).

Architects and facility designers should consult with manufacturers on the proper layout of the AGV System elevator lobbies, as adequate space is required for the robotic vehicles to maneuver under the carts in the send and receive positions. A computer simulation should be developed early in the design cycle to verify the proper number of P&D positions and adequate space to fit them in each area. The "Design Simulation for TransCar Automated Guided Vehicle System (AGVS)" white paper helps determine the number and timing of cart movements, along with the human response time expected for removal of delivered carts along with the preliminary layout prior to start of the simulation effort. A Preliminary Needs Analysis can help the hospital develop this information and a design assist project should engage the supplier early on. Contact Swisslog to conduct a Preliminary Needs Analysis.

Example layout for clean and soiled holding rooms with a single lift.

Example layout for pick up on one side and drop off on the other side.
9. System Control Center

The TransCar Manager Server (and back-up) is usually located on a virtual machine provided by the hospital or on an individual server in a lockable AGV System maintenance room with a computer desk somewhere along the travel path. Users interface to the system via TransCar Manager Clients, which can be individual computers or loaded onto a computer with other applications in the user’s work location.

At least one client should be located in the AGV System maintenance room along the travel path for system operations. This client does not need to be manned full time, but does need to be accessed frequently during commissioning and periodically thereafter for system monitoring, maintenance and configuration changes. The computer room should have emergency and UPS power and an environment of 0% to 95% relative humidity with an ambient temperature of 10°C to 40°C.

The TransCar Manager/Client room should also have a telephone line and Local Area Network (LAN) connections with LAN jacks and broadband internet access (for VPN) plus a phone line with long distance service for voice communications. Users may want the TransCar Manager Clients located in multiple departments where they want the capability to monitor system transports and deliveries. These locations may include materials management, clean linen, central sterile/SPD for case carts, pharmacy and dietary.

10. Robot Vehicle Maintenance Room

A lockable room should be provided for servicing the vehicles and storing operations and service manuals, tools and parts. A parts cabinet, benches, shelving and a place to lay out drawings will be needed. The TransCar Manager Client (and servers if applicable) will be located in this room, along with LAN drops and power outlets. In most cases, a 15-foot x 20-foot space is adequate, and should be configured to enable robot travel into the room directly from the AGV corridor.

11. LAN / WLAN Drops and Configuration

The AGV Control System uses the hospital’s network LAN and WLAN systems to communicate between the TransCar Manager and the vehicles via WiFi and between the TransCar Manager and the elevators, dispatch terminals, battery chargers, I/O controllers and other peripheral devices via LAN.

The server talks to the vehicles frequently over the WLAN, sending small packets of data, so WiFi access is required everywhere the vehicles operate, with roaming capability throughout the entire TransCar travel route. If cart delivery notifications are desired, the hospital’s e-mail system will need to route the server-generated messages to the users who will respond to cart deliveries in specific locations during specific times. Additional LAN and WLAN system requirements details can be obtained upon request from healthcare.us@swisslog.com.

12. Environment

The operating environment should be indoors, temperature controlled between +5 and +35°C (41 and 95° F) with humidity controlled between 30 and 80% and dry.
Throughput Matrix (Bonus Tip!)

The throughput matrix is important information required to properly size the system, and is needed in order to address the quantity of vehicles, charging positions, Send and Receive Stations, elevators/lifts and the vehicle's travel layout. The matrix defines the quantity of full and empty carts that will be moved from and to each pair of send and receive areas in the facility. The matrix should be broken down by hour of the day. To facilitate this assessment, a blank worksheet sample is available from Swisslog by request at healthcare.us@swisslog.com.

Higher returns on investment in AGV Systems can be achieved through leveling transport requirements throughout the day (24-hour period). With this planning, fewer vehicles (less congestion) and fewer chargers are required to meet the peak period cart transport requirements. Start filling in the matrix with the high-priority/time-sensitive cart movements (dietary, case carts) and then fill in the openings with the lower priority movements to level the workload. Waste collection and linen distribution may better be accommodated during the night shift.

The throughput matrix may serve as the data input for an animated computer simulation if the design is complex enough that manual calculations do not provide a high degree of comfort in determining the number of vehicles required or travel network desired.

Optional Equipment/Functionality

Several optional features are available that provide smoother operation and observation of the robotic delivery system.

**Notification System.** The TransCar Manager can be configured to send email messages to the hospital’s email server, including the cart type, destination and floor level. The hospital sets up rules to route those messages (based on the time of day, cart type and cart destination) to the desired user who is responsible for attending to the cart delivered. This is particularly beneficial when the cart contents are sensitive, such as hot patient meals, case carts, or pharmacy deliveries. These notification messages can be sent at time of cart pick-up or upon cart delivery (or both).

**Closed Circuit TV / Digital Surveillance & Recording Systems.** There may be a benefit to installing cameras so that key (or all) AGV travel areas can be viewed at security stations and or the TransCar Manager Client locations. Key areas might include P&D areas, main corridors and the entry and exit of the elevators. Having 100% coverage may be desired for transport of sensitive items such as medications. Additional power and equipment may be required for this hospital-supplied capability.

**Lighted Warning Signs.** “Caution, Automatic Vehicle Approaching” signs may be desired at locations where personnel enter the areas where vehicles are traveling or where there is less than the recommended ANSI clearance space. These are usually mounted to walls or ceilings in adjacent corridors or rooms and flash when vehicles are in the vicinity. The lights can also be equipped with audible warning device. The I/O controller provides low voltage power to these lights and audible devices.

**Room-In-Use/Arrival Lights.** In the absence of a notification system, consideration should be given to installation of three-color status lights. These are located adjacent to each clean/soiled P&D area. Flashing yellow normally indicates that at least one cart has been delivered and is ready for removal from the drop off position. Flashing red normally indicates that all delivery positions are full and the system will back up, since there is no location to deliver more carts. Flashing blue normally indicates that an automatic vehicle is in the lobby/area delivering or picking up carts and can be used in lieu of a Lighted Warning Sign for access controlled areas. The I/O controller provides low voltage power to these lights.

**Rotating Beacon.** Colored rotating beacons or other audible visual warning devices can be supplied to meet special warning or delivery notification requirements. The I/O controller provides low voltage power to these lights.
**Mechanical Trash Dumper.** These can be supplied to assist in dumping heavy carts into compactors or sanitizers. Additional power and equipment is required for mechanical dumpers.

**Automatic Cart Washers.** These may be desirable for frequent and high-quality cleaning/sanitizing of carts. Substantial savings may be achieved in the delivery systems if the carts are cycled between clean and soiled functions each time they are used. Clean meal carts can be used to return soiled dishes. Clean bin-forming linen carts can be used to return soiled laundry. Clean case carts can be used to return soiled instruments sets to decontamination. Clean waste carts can be used to deliver general supplies. Using carts for both clean and soiled transport can significantly reduce the number of carts and the number of cart transports required. Bin-forming or turn-about style carts are great for this type of operation.

Automatic cart washers can be loaded manually or be loaded directly by the robots when equipped with powered tow through conveyors. Additional utilities equipment is required for automatic cart washers.

**Service Support Agreement (SSA).** Manufacturers generally provide an SSA for the robotic cart delivery system, which includes preventive and emergency service at a specified level of response for one to three years past the system acceptance date. Requirements are usually found in the specification for system purchase.

**Preliminary Needs Analysis.** Hospitals considering this technology can request a preliminary needs analysis from their vendors to help them evaluate whether a robotic cart delivery is feasible and justifiable for their facility/operation. If the project shows an acceptable ROI, a design assist simulation and system specification are some of the next steps.

**Summary**

Automated systems operate 24/7. Automated cart transport solutions can streamline material flow in the hospital, control costs, reduce labor and delivery times and free up resources for improving patient care. Materials moved by robots include pharmacy meds, lab samples and reagents, central supplies, linens, general trash, recyclable waste, biohazardous waste, SPD case carts, patient food, bulk food and biomedical equipment.

The determination of whether a facility will achieve lower operating costs by implementing an AGV system should be made very early on in the project design cycle (ideally during the programming phase) in order to accommodate the necessary design requirements up front and avoid subsequent notifications later on. Once the cost-benefit analysis is completed, designers must consider space, flow and adjacency requirements for the AGV elevator core location and connecting lobbies. This is best accomplished through a design assistance project to ensure that all requirements are identified, designs accommodate adequate space and configuration, and space utilization is maximized. Swisslog Healthcare Solutions provides system design analyses to support successful implementation of automation and material transport solutions. Visit our Customer Support portal for more information at hcssupport.swisslognorthamerica.com.
About the Author:

Jeff Barber has been involved in designing, estimating, sales, project management and installation of automated material handling systems for 35 years, including pneumatic tube systems, track vehicles and AGVs, primarily in hospitals. He holds a BS in business administration from Mt. Scenario College in Ladysmith, Wisconsin. Additionally, Jeff completed a management training program with emphasis on electrical and mechanical engineering.

About Swisslog Healthcare Solutions

Swisslog Healthcare Solutions (HCS) is the leading supplier of automation and software solutions for materials transport and medication management in healthcare facilities. Swisslog has installed facility-wide and pharmacy automation systems in more than 3,000 hospitals worldwide, including more than 2,000 in North America. Denver-based Swisslog Healthcare Solutions offers total system design, manufacturing, installation and customer support—providing an integrated solution for lean workflow and operations that enhances information access, patient safety and cost efficiency.