

Safety of automated guided vehicles

A case study in a storage area

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Automated guided vehicles, ie, driverless transporting devices, resemble electric trucks intended for indoor use. The driving mechanisms and bodies may be almost identical. The system comprises one or several vehicles which move under programmed control. The operator has no immediate contact with the system nor has any need to influence it. The vehicles normally follow an electric field formed around electric conductors installed in the floor. System applications include storage-to-production conveyance, use of vehicles as assembly bases, material transfer between production cells and picking tasks.

Typically an automated guided vehicle has the following safety arrangements: (i) low driving speed, which means low collision energy, (ii) an anticollision bumper, (iii) warning signals, (iv) electronic detectors, (v) emergency stop devices, (vi) effective brakes, (vii) devices insuring that the vehicle keeps on the driving track, and (viii) possibility of manual control.

As a conventional truck is often replaced by an automated guided vehicle, it is interesting to compare their safety properties. Table 1 presents major differences between conventional trucks and automated guided vehicles. The changes taking place in the nature of work and in environmental influences are also shown.

A case study was carried out in a factory where an automated-guided-vehicle system was installed into the area of product and raw material storage. In the first stage, attention was focused on the old layout, transporting equipment, material flow, and traffic at crossing points. After the new materials handling system had been used for a while, a new analysis was carried out. The changes in the safety problems, the development of dangerous situations, the changes in traffic and in material flow, and the changes in the personnel's behavior were estimated on the basis of these two comparisons.

In the study, it was presumed that the implementation of the automated-guided-vehicle system in the company concerned would have the following effects on occupational safety: (i) decrease traffic density per time unit as transportation is divided over a longer period of time, (ii) relieve the strong traffic peaks, (iii) reveal deficiencies in guidance, and (iv) initially create operating disturbances.

Methods

Video recordings lasting one whole workday were made of six crossings. A monitoring video and a motion detector were used. The following data could be gathered from the recorded material: traffic types, travel directions, loads, and times of incidents and hazardous encounters. Hazardous encounters were, eg, man-to-truck distances of less than 3 m at a corner or nonexistent visibility.

Video recording was repeated after the change in the materials handling system had been realized at crossings where the automated guided vehicles moved. Great changes had taken place in the spatial arrangements. The amount of transported material and the number of personnel had, however, remained unchanged. Recordings were arranged also at night, as the system operates 24 h a day.

Two video cameras were also attached to the moving vehicle, the objective being to study activity in front of and behind the vehicle. After the system had been in use for about four months, the personnel working in the area were interviewed. The questions concerned, among others, safety changes, disturbances, and danger situations.

Results and discussion

Changes in traffic density

Before the system was changed, observations were made of 2 932 traffic incidents, and, after it was changed, 1 480 incidents were observed. The difference was due to different recording times. The introduction of an automated-guided-vehicle system changed the proportions of various traffic types to some extent. Table 2 illustrates the directions of the changes during a workday.

During a workday, the crossing was passed by an average of 248 pedestrians, 43 fork-lift trucks, and 196 trucks. After the changeover, the corresponding figures were 179 pedestrians, 17 fork-lift trucks, 140 trucks, and 82 automated guided vehicles. Calculated in this way, the number of traffic incidents had decreased by 14 %. Moreover, it must be remembered that an automated guided vehicle carries out a great part of the transportation tasks at night alone; this circumstance has not been taken into consideration in the figures.

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Table 1. Differences between conventional trucks and automated guided vehicles.

	Truck	Automated guided vehicle
Hazards	High kinetic energy Random path Unfavorable conditions for driver	Incomplete safe-guarding Defective decision-making ability Information disturbances
Accidents in Finland	Every 12th truck involved in an accident every year	No accidents so far; mathematically five accidents/year, if same risk level
Basis of safety	Driver's skills Traffic arrangements	Speed three to five times lower Standard paths Stops if disturbed Gives a warning
Applications	General purpose Transfer device	Within a specially designed network
Changes in work	Driver in over every third accident Work sometimes monotonous; poor work conditions Workload peaks Certain skills required of driver	No driver required; no hazards or troubles Does not set requirements on nature of work Applicable in hazardous environments Certain skills and monitoring required of personnel in operating area
Changes in environment	Transportation often separated from production Undeveloped material and traffic flow Unnecessary transferring and storing Damage to materials and structures	Transport system integrated in production Clear layout Controlled material flow Programmed operations Less material damage

At a certain crossing, the number of traffic incidents had increased by 7 % due to the new layout, which had permitted additional through passage at that crossing. At the other crossings, the traffic had decreased by 50 % and dangerous encounters to one-fifth of the previous figures. The crossings were, however, no longer directly comparable. The system change-over can nevertheless be considered to have had a favorable influence on traffic safety.

Hazardous encounters

Of all encounters, 2—4 % were considered hazardous. Table 3 shows the changes of the hazardous encounter observations in the entire material and at two comparable crossings.

As compared with the period before the change, the number of hazardous encounters in the entire area decreased by about 26 or 13 %, depending on whether nighttime was included or not. With the old system the number of hazardous incidents was great in the mornings due to the pallets produced during the night shifts. The second peak was reached before 1400, as there was an attempt to complete the day's truck conveyances in good time before the end of the workshift.

With the new system, hardly any hazardous situations occurred during the morning hours. Instead, between 1100 and 1200 a peak was reached when almost half of the whole day's hazardous situations occurred. The pedestrian traffic was at its busiest then, as was also transportation. It was noted that, in the

Table 2. Proportion of traffic by traffic type.

Traffic type	Old system (%)	New system (%)
Pedestrian	51	43
Fork-lift truck	9	4
Truck	40	33
Automated guided vehicle		20

Table 3. Traffic incidents and hazardous encounters observed with the two systems.

	Traffic incidents (N)	Hazardous encounters	
		N	%
Old system, daytime	2 932	75	2.6
New system			
Nighttime	1 480	28	1.9
Daytime	1 254	28	2.2
Crossing 4, old system, daytime (0700—1400)	549	23	4.2
Crossing A, new system, daytime (0700—1400)	589	23	3.9

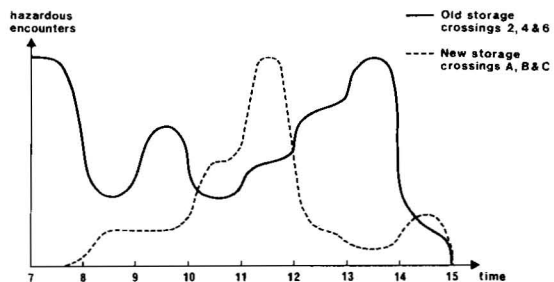


Figure 1. Hazardous encounters at comparable crossings.

new layout, one crossing remained at which almost all dangerous encounters took place. The crossing is next to a production space, and there are many pedestrians there. The total number of hazardous situations has clearly decreased, but at this crossing the situation has remained unchanged. Earlier, every third dangerous incident took place at this crossing. All in all, studies of the dangerous situations show that conveyance safety has improved (figure 1).

Personnel's views of safety features

The various personnel groups of the factory felt that the change in the transport system had improved the work environment. Traffic became clearer and walking distances shorter, more space was available, and loading was more careful. Such considerations are examples of improved safety. The evaluation of safe-

ty problems included, for instance, poorly organized pedestrian passages and unsafe pedestrian behavior, danger points remaining on the gangways, straight

paths which tended to encourage speeding, frequent stoppings of the automated guided vehicle, and lack of training.