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Preventing plant-pedestrian collisions: Camera & screen systems and visibility from the driving position

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ABSTRACT

The issue of collisions between plant or site vehicles and pedestrians concerns numerous sectors of activity. Lack of visibility for drivers over their direct environments is one of the main causes of such accidents, which are often serious. Visibility can be improved indirectly by using camera-and-screen systems. This article gives the findings of a study on the detectability of a pedestrian by a driver using such a system in various configurations. It is thus recommended that, under the most unfavourable conditions, any pedestrian entering the danger zone be shown on the screen with at least a minimum height of 10 mm. Since the risk of non-detection is higher at the edges of the screen than at the centre, it is also recommended that the detection zone of the system cover an area extending beyond the danger zone under surveillance. Finally, since the size of the screen does not have a significant influence on detection, the choice of the screen size should be governed more by criteria regarding the fitting out of and the ergonomics of the cab or of the driving position.

Relevance to industry: Preventing mobile plant-pedestrian collisions is a problem area that concerns many enterprises, in particular in activity sectors like building and civil engineering, handling, transport/logistics and waste collection. Using camera-and-screen systems allows improving the visibility of the driver. This study gives recommendations about choice of such systems, in order to ensure better detection of pedestrians.

1. Introduction

Preventing collisions between plant or site vehicles and pedestrians is an issue that concerns various sectors of activity whenever proximity or coactivity exists between pedestrians and machinery that can move. Examples of such sectors are building & civil engineering (earth-moving vehicles or plant), goods-handling (fork-lift trucks), waste collection (garbage trucks/dustbin lorries), or indeed logistics (trucks/lorries for goods haulage). In order to address this issue, INRS launched a multi-disciplinary research project focussed on systems for detecting people using laser, radio waves, ultrasound, digital vision, etc (Gardeux, 2010; Klein, 2010; Tihay, 2012). Research was also begun on camera-and-screen systems bringing the driver visibility over masked zones (blind spots). Such visual aid or vision aid systems are in increasing use because of the boom in digital technology (with performance improving and costs decreasing). This article gives the findings of a study on the capacity of a driver to detect a pedestrian by using this type of system. The criterion of the height of the pedestrian on the screen is analysed in particular because it has a direct impact on the choice (size of the screen, angle of view of the camera) and the location (distance between the camera and the pedestrian) of the system.

The visibility that a vehicle affords its driver is a decisive factor in preventing collisions between plant or site vehicles and pedestrians. When organisational measures do not make it possible to avoid coactivity situations, it is on the basis of the visual information taken from the surrounding environment that the driver decides on a driving strategy for avoiding the risks of collisions with people, or with other plant or vehicles, moving or standing in the same work space. Visibility is said to be direct or indirect depending on whether the driver observes the exterior elements directly through openings and glazed surfaces of the vehicle or plant, or via mirrors or any other visual aid system (e.g. a camera-and-screen system).

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Many site accidents are related directly to insufficient visibility from the driving position (Marsot et al., 2009). In addition to affecting people moving and standing in the vicinity of the vehicle or plant, risk factors also affect the drivers themselves, who can then put themselves in dangerous situations due to masking of an obstacle, of a slope, etc. Insufficient visibility from the driving position is also a risk factor in back and low back pathologies due to uncomfortable postures taken up by drivers in order to obtain the visual information necessary for their activities (Godwin et al., 2007; Eklund et al., 1994; Hella et al., 1987; Vezeau et al., 2009).

As regards visibility, numerous regulatory or normative texts exist that are intended for plant manufacturers, defining evaluation methods and performance criteria. In this field a distinction should be made between road vehicles (Directive 70/156/EEC, 1970) and mobile machinery, i.e. machinery that can move or travel, in the sense of the "Machinery" Directive (Directive, 2006/42/EC, 2006).

For road vehicles, and depending on the types of vehicle, Directives 2003/97/EC (2004) and 2007/38/EC (2007) set design specifications, installation instructions, and performance requirements for indirect vision systems (wing mirrors, rear-view mirrors, and camera-and-screen systems). For vehicles that are not designed to travel on the road (earth-moving plant, goods-handling trucks, etc.), that information can be found in the European standards that back up the "Machinery" Directive (NF ISO 5006, 2007; NF ISO 13564-1, 2012; NF EN 15830, 2012; NF ISO 14401-2, 2009; NF ISO 16001, 2008). Thus, in order to determine the range of a camera-and-screen system designed for earth-moving plant, Standard NF ISO 16001 (2008) sets at 7 mm the minimum height on the screen of the person to be detected (cf. Fig. 1). This dimension of 7 mm was defined empirically in proportion to the size of the screens then most readily available on the market (with a maximum image's height of 7 cm): "The effective operating range of the system is based upon on a minimum screen height of 7.0 mm. This is approximately 10% of the vertical screen height, which is normally considered acceptable for visual detection purposes" (excerpt from Standard NF ISO 16001).

Analysis of the scientific literature on the use of camera-and-screen systems for combating the risk of plant-pedestrian collisions essentially shows work, in the early 2000s, on defining the hardware configurations necessary for covering the blind spots depending on vehicle type: haulage trucks/lorries, coaches and buses (Tait and Southall, 1998; Rau et al., 2003, 2005), and load-haul-dumpers (HSE, 2001; Godwin and Eger, 2009). Only one of those studies also addresses the concept of "visibility" of the pedestrian. Tait and Southall (1998) thus evaluated two types of camera-and-screen systems (one of which was cheap and the other top-of-the-range for the time). Twelve conditions were presented to three drivers: daytime and night-time, and with and without a test object/test body (A 1-m high, 75-mm diameter grey plastic pole, defined in Standard ISO TR 1255 (1994)) in the field of the camera. The images from the camera were shown for 0.5 s to each subject, who then had to indicate whether or not the target was present. On average, the target was not perceived in 14% of the cases under daylight conditions, and in 50% of the cases under night-time conditions. The authors explain these low performance levels by the distortions generated by the cameras that were used at the time.

Given the progress, in recent years, in the performance of camera-and-screen systems (going over from analogue to digital) and in the dimensions of the screens (8.9 cm (3.5 in) diagonal screens replaced by 12.7 cm (5 in), 17.8 cm (7 in), or 25.4 cm (10 in) screens), we launched a study to confirm or to invalidate the following hypotheses:

- **Hypothesis 1**: the smaller the pedestrian is on the screen, the higher the number of non-detections.
- **Hypothesis 2**: the smaller the screen, the higher the number of non-detections.
- **Hypothesis 3**: the larger the angle of view of the camera, the higher the number of non-detections due to distortions of the image.

Test these three hypotheses aims to establish the criteria for choosing a camera-monitor system, with focus on the detection of pedestrians in the vicinity of the vehicle to avoid a collision, as never done before. Moreover, camera's angle, screen size and height of the pedestrian on the picture are three criteria that have previously not been taken into account simultaneously in previous studies.

2. Material and method

2.1. Material: camera-and-screen systems

A representative sample of the cameras and screens that were currently available for equipping mobile plant and site vehicles was selected for this experiment. Usually, manufacturers propose complete sets, with the cameras and screens being of the same make. In order to cover all of the characteristics considered, we intentionally selected the cameras (3 cameras) and the screens (3 screens) individually. The connectors were adapted so that each of the screens could be connected to all of the cameras.

The main selection criterion for the screens was their size: 12.8 cm, 17.8 cm and 25.9 cm diagonal. The main selection criterion for the cameras was their angle of view. Three families of angle of view are generally recommended, each being appropriate for a particular characteristic situation. All of the angles of view mentioned below correspond to horizontal angles (some

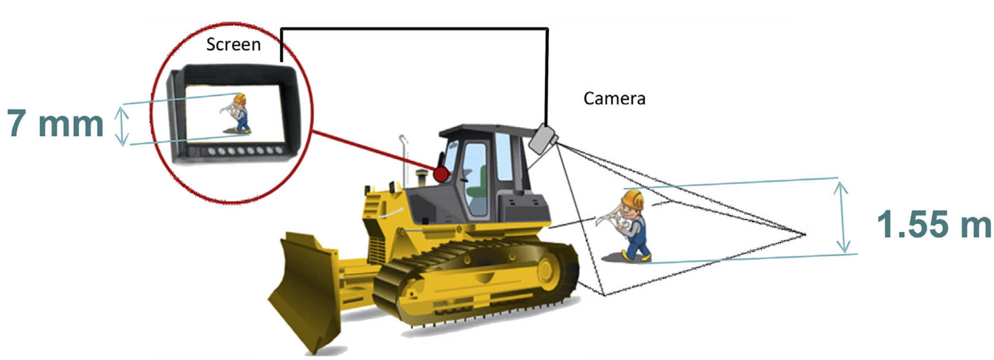

Fig. 1. Illustration of the height condition for determining the limits of detection of a camera-and-screen system (NF ISO 16001, 2008).