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Product liability for ADAS; legal and human factors perspectives

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A variety of Advanced Driver Assistance Systems (ADAS) has been and is still being developed, aiming to make car driving more comfortable and safe, while at the same time enhancing traffic efficiency. However, the successful implementation of ADAS is affected by a variety of technical and non-technical issues, one of them being possible implications in the field of legal liability. Potential liability of system developers and car manufacturers is often labelled as a barrier for the rapid deployment of new technology.

In the present contribution the European Product Liability Directive's concept of a defective product is described and analysed from both a legal and a human factors perspective. In legal debates concerning product liability, generally two different approaches can be distinguished, one which is based on consumer expectations and a second which focuses, rather, on a risk-benefit analysis. As will be explained, the two may be seen as complementary and not as being mutually exclusive. Both tests can only be properly applied with the help of human factor expertise.

1. Introduction

A variety of Advanced Driver Assistance Systems (ADAS) has been and is still being rapidly developed by the automotive industry. Electronic devices such as route guidance, adaptive cruise control, collision avoidance, lane keeping and lateral control systems, inform or actively support the driver to improve the critical task of driving a motor vehicle. Potentially, these 'smart' systems offer important advantages for road safety and driver comfort. Furthermore, equipping vehicles and infrastructure with intelligent technology may contribute to reduce congestion and the environmental impacts of road traffic.

The successful implementation of ADAS is affected by a variety of technical and non-

technical issues, one of them being the liability implications of introducing such new technologies in road traffic (RESPONSE 2004; Commission, 2003). As soon as ADAS (in active support variant) take over drivers' observations, judgements and decisions, the introduction of these systems raise questions about the consequences with respect to legal responsibilities for accidents. One of the most prominent question in this context is to what extent the use of ADAS may shift liability for road accidents from drivers to car manufacturers and system developers and whether current liability regimes are suited to accommodate the introduction of ADAS.

In Europe product liability law is, to an important extent, governed by the European Product Liability Directive. This Directive provides a common (but not exclusive) basis for product liability claims in the EU. Most important element of this liability regime is the legal concept of a 'defective product'. This article tries to provide some insight in questions of product liability in relation to ADAS by analyzing the Directive's concept of a 'defective product' from both a legal and a human factors perspective.

2. The European Product Liability Directive

The European Council Directive on liability for defective products was adopted in 1985 (Council Directive 85/374/EEC, OJ 1985, L. 210/29). The first recital of the preamble to the Directive explains the motives for drafting this Directive:

“Whereas approximation of the laws of the Member States concerning the liability of the producer for damage caused by the defectiveness of his products is necessary because the existing divergences may distort competition and affect the movement of goods within the common market and entail a differing degree of protection of the consumer against damage caused by a defective product to his health or property.”

Article 19 requires Member States to implement the Directive, which means that the Member States must bring into force national laws, regulations and administrative provisions necessary to comply with the Directive (article 19). The Member States are not allowed to deviate from the Directive in favour of manufacturers, nor are they allowed to draw up new legislation to impose higher obligations on producers and suppliers or to create higher levels of protection for consumers. For example, the European Court of Justice (ECJ) concluded that both France and Greece had failed to implement the Directive correctly because they did not make provision in its national legislation transposing the Directive for the minimum claims threshold of 500 euro (Case C52/00[2002] ECR I-3827 and C -154/00 [2002] ECR I-3879).

In addition to the obligation for legislators to implement the Directive in national laws, national courts are obliged to interpret national product liability laws in conformity with the European Directive when applying them in individual cases (Dommering - van Rongen, 2000). Furthermore, matters of interpretation of the Directive are eventually to be decided by the ECJ.

Although the European Directive on liability for defective products has an important harmonizing effect, it did not result in a complete harmonization of European product liability law. The Directive provides a common, but not exclusive, basis for product liability claims in the EU. National differences in liability for defective products still exist. (Melzer et

al., 2003). Inter alia, this is because the Directive has a restricted scope and does not affect systems of liability under the laws of contract and tort liability, as well as special liability systems that existed prior to the Directive. In a recent study, however, it was concluded that there is little evidence that disparities between Member States in the practical functioning of product liability regime create significant barriers to trade or distortions to competition in the EU (Melzer et al., 2003).

According to the preamble of the Directive its aim is not only to harmonize national product liability laws, but also to provide a satisfying level of consumer protection. For this reason the Directive did not introduce a system that requires proof of breach of a 'duty of care' (negligence) but one in which liability is dependent on proving that a product is 'defective' and that it caused damage.

The major distinction between traditional fault-based principles of liability and the principle of liability under the Directive is that the former focuses on the conduct of the manufacturer or supplier (the claimant must identify someone whose act or omission has caused harm and must prove that this was attributable to that person's negligence or by the negligence of an employee), whereas the latter focuses on the characteristics of the product, more specifically whether the product contains a "defect" that causes damage. The second recital of the preamble to the Directive motivates this as follows:

"Whereas liability without fault on the part of the producer is the sole means of adequately solving the problem, in particular to our age of increasing technicality, of a fair apportionment of the risks inherent in modern technological production."

However, despite this 'strict liability' rhetoric, as Stapleton formulates it, most commentators agree that this supposed 'strict' character of the liability regime of the Directive should be regarded to be rather limited, primarily as a consequence of the problems of establishing defectiveness and causation and because of the various defenses available under the Product Liability Directive, including the development risk defense (Stapleton, 1994: pp. 236; Dommering - van Rongen, 2000: pp. 36; see also Section 4.6). In fact, the liability regime of the Directive has often been characterized as 'superficially strict, but substantially fault-based' (Miller and Goldberg, 2004: pp. 210-211).

3. The legal concept of a defective product.

The most important element of the European Directive is the notion of a defective product. According to the Directive the producer shall be liable for damage caused by a *defect* in his product (article 1). Article 6 (1) of the Directive provides a definition of a defective product:

"A product is defective when it does not provide the safety a person is entitled to expect, taking all circumstances into account including:

- a) The presentation of the product;
- b) The use the product could reasonably be put to;
- c) The time when the product was put into circulation."

A product being defective in this legal sense means being unsafe rather than inadequate for its intended use. In other words the defectiveness of the product will not be determined by its fitness for use, but by the level of safety that is reasonably expected of it. Often, these two qualifications will overlap, but this is not always the case. A new car that does not start is not fit for use, but will not be found defective in the sense of the Directive. However, if electronic safety functions of a (newly bought) car suddenly fail this may well establish a safety defect that will be relevant in terms of the product liability law.

A major difficulty of the definition of a defective product in article 6 of the Directive is its vagueness. It fails to provide readily ascertainable objective standards against which a manufacturer or a court can measure the safety of a product (Kullmann, 2004: pp. 96; Miller and Goldberg, 2004: pp. 354; Dommering - van Rongen, 2000: pp. 43). In fact it could be stated that what a person is entitled to expect is the very question that a definition of defect should be answering (Stapleton, 1994: pp. 234).

Because of the vagueness of the concept of “defect”, it might be suggested that the concept should be more precisely defined in the Directive. On the other hand, it could be argued that it is better not to attempt to define the concept with too much precision, not in the least because this could restrict the ability to judges to deal with matters on a case-by-case basis. However, it might be expected that in time, as experience of use of the Directive in litigation grows, there will emerge a body of case law that will provide a guide to the interpretation of the concept of “defect”, i.e. that this concept will come to be clarified in due course by the courts of the Member States and the ECJ (Melzer et al., 2003: pp. 48)

Article 6 provides a non-exhaustive list of circumstances which are to be taken into account in determining what people generally are entitled to expect in relation to a product.

(a) The presentation of the product;

The presentation of the product includes all product information such as advertisements, instruction manuals, user handbooks and warnings placed on the product. Because of the innovative nature of ADAS, the presentation of the product could become a crucial element in future product liability claims. Manufacturers can influence the safety expectations of consumers (and thereby their liability risk) both positively and negatively by the presentation of the product. Inadequate presentation or instructions can thus make a system defective that could otherwise be regarded safe enough (Van Wees, 2004: pp. 181). It is of critical importance that potential users are not only aware of the functional characteristics but also properly understand the operational characteristics of the system, i.e. they understand its limitations. Manufacturers are required to keep a careful balance between spelling out system limitations and potential dangers with sufficient clarity and emphasis, even when doing that would in a way detract significantly from sales. They should refrain from unrealistic claims about system performance and should never understate known or potential hazards (RESPONSE, 2001: pp. 65). The attention of potential customers is much more easily drawn to bright colors, shiny appearance and nice presence than to dry warning messages.

(b) The use the product could reasonably be put to;

Reasonable anticipated use comprises more than the intended use of a product. In the preamble of the Directive it is stated that the defectiveness of the product should be determined by reference not to its fitness for use but the lack of safety which the public at large is entitled to expect while safety is assessed by *excluding any misuse not reasonable*

under the circumstances. This means that, reasonable anticipated use of ADAS implies that manufacturers must take into account all possible users when designing a system and deciding on accompanying warnings and instructions, which may include ‘vulnerable’ system operators. For instance, in German courts the standard applied is “the least informed and most endangered user” (Kulmann, 2004: pp. 98; RESPONSE, 2001: pp. 55). In case of ADAS this may concern novices or elderly drivers. Furthermore, it implies that not the most careful consumer will be the standard to judge the required safety level of a product, but the average driver that may have moments of carelessness and lowered attention (Van Wees, 2004: pp. 185). For instance, at times when physical fitness is not optimal because of (slight) illness or drowsiness. Sub-optimal physical fitness may, for instance, decrease the likelihood of detecting malfunctions of the system at hand (Brookhuis et al., 2003b).

(c) The time when the product was put into circulation.

The time when the product was marketed is also one of the relevant circumstances in determining the defectiveness of a product. First of all, the time of marketing relates to the state of the industry or the state of the art. The required level of safety that a product should provide will be influenced by the availability of safer alternatives on the market. If these are available (and economically feasible), perhaps then the product should have been (re)designed with safer functional or operational characteristics. This of course does not mean that the safest product on the market will be the product liability standard. Other factors, such as the price of the product will be relevant as well. One will certainly have greater chance to survive a car crash in a upper class Mercedes than in a low priced car on the market, but this does not mean that the latter one is defective due to lack of ‘crashworthiness’.

The time of marketing also plays a key role in the so-called ‘development risk defence’. According to the Directive, the producer shall not be liable if he proves “that the state of scientific and technical knowledge at the time when he put the product into circulation was not such as to enable the existence of the defect to be discovered” (article 7 (e) of the directive).

The aim of this development risk clause is that no manufacturer can be held liable if the defect in the product was undiscoverable given the state of state of scientific and technical knowledge at the time of marketing. The clause was defined in order to establish a satisfactory compromise between the need to stimulate innovation and consumers’ legitimate expectations for safe products. (Fondazione Rosselli, 2004).

4. Defectiveness standards and ADAS: consumer expectations versus risk benefit

In legal debates concerning the question how to determine the ‘defectiveness’, i.e. what standard to apply to judge a product defective, generally two different approaches are highlighted, namely one which is based on consumer expectations and a second which focuses, rather, on a risk-benefit analysis. As will be explained, the two may be seen as complementary and not as being mutually exclusive (Miller and Goldberg, 2004: pp. 355).

4.1 Defectiveness standards in relation to manufacturing defects

From the wording of article 6 – a product is defective when it does not provide the safety a person is entitled to expect – it can be concluded that the EC Directive defines "defect" in terms of consumer expectations. This consumer expectations standard is an objective one (Dommering – van Rongen, 2000: pp. 43), meaning that the expectations of the individual consumer are not significant except to the extent that they are a reflection of more general public expectations (Miller and Goldberg, 2004: pp. 367). In many cases this definition will not be a problem in application. For example, no one will expect the brakes of a new car to fail.

More generally, determining consumers' legitimate expectations will normally not raise many problems in relation to so called manufacturing defects. A manufacturing defect exists when a product (a vehicle, vehicle parts or vehicle equipment) does not meet the manufacturers' own product specifications. In other words, the product deviates from the product-line-standard. It is estimated that 60-70% of the product liability cases concern manufacturing defects (Greenpaper Liability for defective products, 1999). Such defects might be the result of raw materials or components containing physical flaws or the fact that some 'error' occurred during the production phase or the assembly into the final product. For example, it could happen that by accident some badly produced sensors have been used in one or more ADA-systems.

4.2 Defectiveness standards in relation to design and presentation defects

In cases of so-called design and presentation defects the application of a consumer expectation test will often become problematic in its application. Products (vehicles or vehicle equipment) that comply with the product-line standard might still be defective in terms of product liability law. That is because the product design itself can be unreasonably unsafe or instruction or warnings accompanying the product can be considered inadequate.

These types of potential defects will be particularly relevant in the field of ADAS. Although today's developments in the field of sensor- and computer technology create an enormous range of possibilities to enhance drivers' safety, automating the drivers' task will also introduce new safety concerns that could generate defectiveness claims. For instance, an important aspect of these systems is that the input of the system is formed by actual traffic conditions. There is a great diversity in traffic conditions (other vehicles, non-motorised road users, road geometry, etc.). Based on these conditions the system will decide to warn, brake, accelerate or steer automatically. Ideally, testing should include all possible situations. Fact is, however, that real world traffic will probably always be more varied than could be foreseen in the most comprehensive testing.

4.3 Human factors and ADAS

Another safety concern (and potential 'source of defectiveness') is the consequence of 'human factors' for ADAS. For instance, drivers' poor understanding of system performance and limitations may lead to dangerous situations. Although the purpose of ADAS is to have a positive effect on traffic safety, negative effects on driver behaviour have been found as well, and with that, negative effects on traffic safety (Van Winsum, 1997; Hoedemaeker and Brookhuis, 1999). Firstly, the provision of information diverts the driver's attention from traffic. Secondly, handing over (part of) the driving task to a co-driver system is sometimes

known to produce behavioural adaptation (Dragutinovic et al., 2004). Consequently, either the driver might not (or too late) be aware of a sudden hazard, or, is not fit (anymore) for an adequate reaction (Brookhuis et al., 2003b). Central problem is that human beings are poor 'process monitors' (Molloy and Parasuraman, 1996), i.e. they are not good in monitoring and supervising (automated) systems. Many examples of accidents can be found in the literature, where the operator missed crucial signals such as danger indications while monitoring or supervising systems. In particular highly automated systems such as found in air transport are well-known sources of accidents for that reason. Before introducing any ADAS, the consequences of system operation in this sense should be identified and stipulated.

Automation increases reaction time and might even cause complacency (over-reliance). Some ADAS studies found evidence for complacency, i.e. excessive reliance on ADAS (De Waard et al., 1999; De Waard et al., 2004); others reported loss of driving performance. Ward, Fairclough and Humphries (1995) and Ward (1996) found complacency in poor lateral position control, and additionally, failure to yield to other traffic was more frequently observed in drivers driving a car with an ADAS (in this case Adaptive Cruise Control) compared to drivers driving a normal car. Behavioural adaptation should be taken into account when investigating the conditions for introduction of ADAS (Verwey, Brookhuis and Janssen, 1996; Dragutinovic et al., 2004).

Of additional importance is whether drivers have any trust in automated vehicles, whether they will actually reclaim control when required, which driving mode they prefer, and whether they will accept supervision over an automated vehicle instead of driving themselves. Studies on an Automatic Highway System have demonstrated that drivers supervising a fully automated transport system often do not reclaim control in critical situations, or at least not in time (Desmond, Hancock and Monette, 1998; De Waard et al., 1999), whereas this is obviously crucial when supervising a vehicle with passengers or dangerous goods.

In a recent driving-simulator study (De Waard et al., 2004) on a hybrid automated public transport system on the road, bus-drivers could switch from fully automatic (type: underground / metro) to semi-automatic control (type: tram, i.e., longitudinal control operated by driver, lateral control by vehicle) to manual (type: bus). The driver was instructed to supervise the performance of the vehicle when in (semi)automatic mode and reclaim control if necessary. The study shows that drivers in the automatic mode, i.e. being supervisors only, did not respond adequately, i.e. in time, to crossing traffic. Training for a couple of hours was sufficient to teach the driver how to stay-in-the-loop and respond properly.

4.4 Problems with a consumer expectations test and the relevance of risk-benefit considerations in relation to ADAS

The question is of course which inherent limitations or harmful side effects could be regarded acceptable and which might render an ADA-system to be judged not reasonably safe?

In some design cases there is no dilemma: where the relevant aspects of the design prevents the product performing the task (or the range of tasks) which all would agree such a product is expected to perform. For example no one would expect an air bag to deploy when there is no accident or the electronic systems in a car to be short-circuiting. However, in other cases

answering the defectiveness question on the (sole) basis of a consumer expectation test is far more difficult. It appears to be especially problematic in relation to complex and innovative products and obvious and warned dangers (Miller and Goldberg, 2004: pp. 357).

The problem with the application of a consumer expectation test in the context of complex and innovative products such as ADAS is that users may have generally no idea how safely a product ought to perform in all foreseeable situations, or how safe it should be made against all foreseeable hazards (Miller and Goldberg, 2004: pp. 403). Furthermore, due to lack of experience, expectations of consumers have not yet been sufficiently established to define an expected standard of performance.

Another problematic implication of a consumer expectation test as the sole basis for determining design defectiveness is that liability of the manufacturer will be denied in all cases where the danger was obvious or warned for. In many cases this will be an appropriate outcome: the behaviour of the claimant and not the design or presentation of the product should be considered the primary cause of injury (Miller and Goldberg, 2004: pp. 377). While some modern motor vehicles can speed up to even 200 km/hour, thus creating very dangerous situations, we find it hard to imagine that a court will judge such a car defective for that reason. Or, to take examples from German case law, manufacturers of chocolate bars or liquorice are not liable for damage caused by excessive consumption of their products (Brock, 2004; Kempe-Müller and Hieke, 2004; Hannes, 2003).

The point is that, although the fact that a danger is widely known or obvious will often suggest that a product has achieved the level of safety which persons generally are entitled to expect, there are also cases where denying liability for patent dangers should be regarded too simplistic (Miller and Goldberg, 2004: pp. 377). For example, an ADA-system might not be excluded from being qualified as defective, because safer design options were available and economically feasible. Manufacturers cannot simply restrict their liability for products that do not meet an acceptable level of safety by arbitrarily defining only one specific use as 'normal' or by the mere statement that, because systems can be overruled by the driver, responsibility remains (entirely) with the driver (Van Wees, 2004: pp. 183; RESPONSE, 2001: pp. 256). It is their primary duty to market a safe product. This might, for instance, imply a duty to design a system in such a way that it cannot be used in a hazardous manner or under hazardous circumstances (for instance speed ranges or type of roads the system was not designed for).

4.5 Applying a risk-benefit test

Although the Directive defines a 'defect' in terms of consumer expectations and does *not* provide an explicit defense based on risk-benefit considerations, nonetheless the following can be argued. Given the difficulties of applying a consumer expectation test in relation to complex and innovative products as well as obvious and warned dangers it seems almost inevitable that the standard of safety which persons are entitled to expect will in cases of alleged design and presentation defects depend in part on weighing the risks and benefits associated with the product. In other words, if judges will assess legitimate consumer expectations the question can soon become one of only being entitled to expect from producers what is reasonable (Miller and Goldberg, 2004: pp. 356).

It can be defended that a (complementing) risk-benefit approach does also fit in the framework of the Directive. Applying a combined consumer expectation-risk-benefit test in

cases of complex products and obvious or warned dangers might be judged consistent with the wording of the Directive since “all circumstances” should be taken into account in determining what persons are generally entitled to expect (Miller and Goldberg, 2004: pp. 416-417). Or in the words of Stapleton (1994: pp. 236):

“The core of the ‘defect’ enquiry will substantially parallel the issue which underlies the negligence standard – the trade-off between risk-taking and social cost as reflected in the magnitude and gravity or risk, balanced against the cost of precautions and social utility.”

Until now, however, it seems that the relevance of the risk-benefit analysis in the context of the Product Liability Directive regime remains largely unanswered by the courts of the Member States and the ECJ (Miller and Goldberg, 2004: pp. 362; RESPONSE, 2004: pp. 104; Melzer et al., 2003: pp. 47-48).

Although a risk-benefit approach might help to solve some of the problems in applying a consumer expectation test (considering consumer expectations just one factor in the assessment of defectiveness) it is not without difficulties.

A first major difficulty associated with a risk-benefit approach is the complexity of assessing risks and benefits since balancing factors should be somehow comparable and quantified in comparable values, preferably in monetary terms.

However, design decisions often involve trade-offs between factors of a very different nature. For example, a car can be made safer in terms of crashworthiness, but using more metal in the car doors to withstand crashes means higher fuel consumption, lower brake efficiency, and so on (Stapleton, 1994: pp. 267).

Furthermore, figures on the cost-effectiveness of an alternative design or presentation of an alleged defective product are at best crude estimates and generally not available to courts, therefore making judgement of courts to a large extent an intuitive one. This may be illustrated by the judgement of warning defects. Under the Product Liability Directive’s strict liability regime, the person injured by a defective product must prove the damage, the defect, and the causal relationship between defect and damage. Translated into the context of defects through an alleged failure to warn, the causation requirement demands not only that claimants prove the feasibility of a warning, but also that, had a warning been provided, they would have heeded it, thus avoiding the accident (Stapleton, 1994: pp. 253). Faced with a court insisting on proof of the requisite causal link between her injury and the inadequacy of warnings, a plaintiff would find little comfort in modern human-factors studies about the efficacy of warnings. They reveal that excessive warnings, particularly of obvious hazards, are counterproductive causing people to be lulled into a false sense of security. A warning, to be effective, should be carefully calibrated in the sense of being decipherable, comprehensive, parsimonious, obvious and executable (Wielenga and Brookhuis, 2005). In spite of the importance attached to warnings in some product liability cases, both behavioural and scientific research shows that most people do not heed them, suggesting that excessive warnings are counter-productive, since people become accustomed to warnings and tend to ignore all of them. Even when consumers are confronted with adequate warnings, i.e. sufficiently adequate to appraise users of the risks and how to use a product safely, they do not always read, understand, remember, or comply. Psychological and consumer behaviour studies show that inattention to warnings is the inevitable result of limitations in cognitive

capacity, memory, attention –span or capacity, and time-pressure. Warnings may also fail because people (willingly) ignore them and rely on explanations provided by human intermediaries or on so-called general knowledge and experience (Miller and Goldberg, 2004: pp. 470).

4.6 Problem awareness: the discoverability of risks

Another problem with the application of a risk-benefit test is that risks need to be known before taking them into account in the design and the presentation of the product. This is also expressed in the Directive's so-called Development Risk Clause which stipulates that no manufacturer can be held liable if the defect in the product was undiscoverable given the state of scientific and technical knowledge at the time of marketing. However, the problem is that knowledge about product risks often emerges slowly. This may be so because such risks were not yet subject of scientific curiosity or creativity, or because evidence of risks accumulates and the data on a causal relationship need to be sufficient to be statistically relevant. This will also be true for ADAS. Although behavioural scientists warn for the potential risks following from automating the driver's task in terms of poor comprehensibility of system performance, decreasing levels of attention and complacency, the quantification of the risks is far from easy (see Brookhuis, De Waard and Fairclough, 2003).

Although the Directive provides a possible defense for manufacturers if the defect in the product was undiscoverable given the state of scientific and technical knowledge at the time of marketing, it may be assumed that in fields of innovative technology such as ADAS, manufacturers cannot passively rely on the current state of knowledge. In areas of rapid innovative development which may outstrip existing safety research, a heavy burden rests on manufacturers to discover what aspects of their products may be harmful. (Miller and Goldberg, 2004: pp. 514). They have an obligation to actively investigate the possible dangers of their product, including human factors (Van Wees, 2004: pp. 199; RESPONSE, 2001: pp. 269). This implies for instance the investigation of driving behaviour of different driver categories in experimental situations (RESPONSE, 2001: pp. 270).

However, the Directive gives no guidance as to what are sufficient measures to enable a defect to be discovered (Van Wees, 2004: pp. 199; Miller and Goldberg, 2004: pp. 507). In other words, how much time and effort should be spent on identifying potential hazards before they may be called undiscoverable? Again, this seems a question which can only be determined by some notion of what is *reasonable* to expect of the defendant (Stapleton, 1994: pp. 241), i.e. by some risk-benefit test (Miller and Goldberg, 2004: pp. 507).

In relation to the 'discoverability' of a defect, it should be emphasized that defects which remain undetected and unappreciated by what may be termed limited general knowledge are treated differently and do not allow the defendant to utilize the development risk defence. This is because the defect may not be unforeseen, not through a lack of scientific and technical knowledge, but because of the failure to put obvious facts together to appreciate and eliminate (or reduce) risks (Miller and Goldberg, 2004: pp. 515; Van Wees, 2004: pp. 200).

4.7 Acceptance of risks

A last and important difficulty in applying a risk-benefit test in the context of the product liability law is the fact that some risk of the same magnitude (in terms of persons killed or wounded, etc.) are more acceptable than others. In other words, social and legal acceptance also depends on the type of risk.

From a legal perspective this can be illustrated by the apparent exclusion of the development risk defense in relation to manufacturing defects. It is broadly assumed that the fact that such incidental defects can not always be detected and prevented, not even with the most advanced control measures, this will not exclude the producer from liability (Miller and Goldberg, 2004: pp. 395; Stapleton, 1994: pp. 248). The German Federal Supreme Court also expressed this view in a case where a person was injured as a result of an exploding bottle of mineral water (BGH 5 May, 1995; ZIP, 1995: pp. 1094). This was caused by a very fine hairline crack that was not practically detectable before bringing it in circulation (there had been seven inspections by the bottler). The German Federal Supreme Court's verdict was nevertheless that the bottle of mineral water was defective because it did not guarantee a degree of safety which may justifiably be expected, taking all circumstances into account.

It seems that in case of manufacturing defects, no account is being taken of risk-benefit considerations. The rationale behind this reasoning is that the damage caused by these incidental production errors should not rest on the individual product user that was so unfortunate to be confronted with this 'below production-line-standard product', but should rest upon the manufacturer who is able to spread these liability cost over the whole community of product buyers. Liability for manufacturing defects is therefore normally not controversial. Not surprisingly, these claims regarding manufacturing defects are typically settled outside court (Stapleton, 1994: pp. 252).

Questions of the relative acceptability of risks in the context of the Product Liability Directive also rise in cases of defects or risks which are known in general terms, but are entirely unpredictable and undetectable in their incidence. These types of defects or risks may also be an issue in relation to ADAS, primarily because of the technical difficulty to design intelligent software-based systems that are able to deal with all situations that may be encountered in daily life traffic. For example, ideally, software should be designed in such a way that a system would function in a predictable and safe manner under all circumstances. However, conditions in real life traffic will probably always be more varied than was foreseen in the most comprehensive design and testing process. It is assumed that in practice it is impossible to produce bug-free software. Full pre-circulation screening for complex software programs in ADAS would be, if feasible at all, astronomically expensive. The question is however, whether the practical impossibility to design bug free software should be a defense for the manufacturer who is confronted with the poor fellow who tragically 'discovered' the software bug.

It may be doubted that in these types of cases courts will allow a manufacturer to defend himself on the basis of a risk-benefit argument, i.e. that the general benefits to society outweigh these incidentally and unpredictably manifesting risks (Van Wees, 2004: pp. 235).

5. Conclusions and final remarks

Potential liability of manufacturers and suppliers is often labeled as a constraint for the introduction of ADAS. Most important element of the European Product Liability Directive is the legal concept of a 'defective product'. The Directive basically defines a defect in terms of a consumer expectation test: a product is defective when it does not provide the safety a person is entitled to expect. Although a consumer expectation standard will in many cases not lead to problems in its application – no one will expect the brakes of a new car to fail or an ACC-system to prevent control of the brakes - in other cases, especially cases of alleged design or warning defects, it may be a problem. This is particularly true in relation to: 1) complex and innovative products 2) obvious or warned dangers. The difficulties in applying a consumer expectation test as the sole basis for assessing defectiveness, seems to create the need for an additional risk-benefit analysis to establish whether an ADAS is defective. It can also be defended that elements of a risk-benefit test can be fitted in the framework of the Directive, because the Directive allows courts to take all circumstances into account. However, case law is not clear on the matter.

Although a risk-benefit approach may help to solve some of the problems in developing and applying a consumer expectation test (considering consumer expectations just one factor in the assessment of defectiveness), it is not without difficulties.

First of all, design decisions in many cases involve trade-offs between factors of a different nature (for example comfort versus safety) that are difficult to balance in a cost-benefit analysis. Furthermore, figures on cost and benefits are often only crude estimates at best, making court judgments to a large extent intuitive. Finally, in cases of a manufacturing defect, risk-benefit considerations are not likely to be taken into account because it is felt that the damage caused by (incidental) production errors should not rest on the individual product user.

Despite the fact that some important factors can be identified that will be relevant for determining the potential defectiveness of an ADAS, it has been made clear in this contribution that no hard and fast rules can be given to answer the question what will be safe enough. This may certainly make manufacturers feel uncomfortable. However, one should not rush into categorical statements about product liability as a barrier for market introduction. On the one hand it is basically a valuable principle that judges take all the relevant circumstances into account. One of these circumstances, for instance, will be the possibilities for producers – also considering the burden in terms of costs, time and trouble - of taking precautionary measures against the inherent shortcomings and resulting dangers of ADAS. It forces manufacturers to carefully design, introduce and monitor their systems. Product liability stresses the responsibility of the industry and is far more flexible than vehicle safety regulation (Van Wees, 2004: pp. 234; Van der Heijden and Van Wees, 2001).

This being said, however, we could still agree that it would be undesirable if system developers and car manufacturers are discouraged to develop and market ADAS only because the (perceived) liability risks are too high. Product liability is often labeled as an important 'show stopper' for the market introduction. Certainly, more advanced ADAS such as anti-collision systems that intervene in critical situations, will because of the consequences potentially raise serious and difficult product liability questions which may need some legal intervention.

However, one should not put all the blame on liability. First of all, the threat of product liability will have a preventive effect, helping to keep immature or poorly designed technology off the market. Secondly, an important observation in this respect is that, although product liability is getting a lot of attention in the legal literature, case law on the subject, especially in relation to the automotive sector, is rather rare. Of course, this may certainly not be considered the only indication whether or not product liability must be regarded as a threat for the deployment of ADAS. For instance, most claims will probably not reach court, because manufacturers prefer settlement outside court. Collecting evidence about such settlements is almost an impossible task (Fondazione Rosselli, 2004: pp. 9) It appears, however that in Europe (automotive) producers are, in contrast to the United States, until now not burdened with a great number of claims (Reimann 2003; Van Wees 2000; Castaign, 1994). Recent evaluations of the Product Liability Directive did not reveal any serious problems of the automotive industry with this Directive either. Furthermore, the introduction of other innovative automotive technologies such as navigation systems, ABS, ESP or ACC do not seem to be seriously limited by the impact of the product liability law. Of course this does not mean that new technologies will not raise new liability concerns for manufacturers. There may always be opportunistic claimants trying to shift their damages based on the argument that the manufacturer should have brought a safer system on the market or that the presentation or the lack of warnings/instructions rendered the product defective. This, however, does not mean that such a claim will be accepted in court.

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