

loads on the axles, maximum heights, pneumatic springs, turning circles and the safety guards that should be in place to prevent cyclists and pedestrians from going under the wheels of a truck. Trucks have to be certified as meeting certain safety standards before they are allowed to be driving on the roads in the Netherlands.

The engineers used only two requirements of this regulative framework, the maximum allowed weights and the maximum allowed heights as specified in the framework. They decided not to familiarize themselves with the rest of the framework because they did not consider it relevant for their design task, i.e., the design of a reliable lightweight trailer using composite materials. Moreover, the design engineers realized that all parts of the regulative framework that included references to material properties had been written with the idea that the product would be made of metal.

All other decisions concerning safety were based on internal design team norms. These norms were based on the type and level of education of the engineers, more than half of them had a Master's degree in aerospace engineering, and of the design experience of the engineers and of the engineering company involved. Within the engineering company there was a lot of experience with lightweight design and the use of fiber reinforced plastic composites. This experience had led to company norms regarding what constituted a good and safe design. For example, an internal norm on good lightweight design was that material should only be added to places where loads were supported. Another example was that, when making a design out of composite materials, a new configuration needs to be made, it is not sufficient to copy a configuration used for non-composite materials. Personal experience did not play a large role in this design process.

With the operationalization of safety as structural reliability, the engineers neglected traffic safety. They only felt responsible for designing a reliable construction. Within the company, no one had experience with traffic safety measures and therefore there were no internal company norms relating to traffic safety. Nevertheless, many of the important ethical issues regarding trailers are related to traffic safety. People can be killed in accidents with trucks and trailers, for example cyclists or pedestrians can be run over if a truck driver fails to see them when turning a corner. Moreover, the engineers decided where the heavy and stiff elements of the trailer should be situated. This decision influences traffic safety because it determines the elements that will hit other traffic participants during a collision (Van der Burg and Van Gorp, 2005).

## **4 Discussion and Conclusion**

The case studies show a clear difference between how ethical issues are dealt with in normal and in radical design. In the case of normal design, ethically relevant choices were made on the basis of existing regulative frameworks, arising from regulations and standards. Operationalizations of ethically relevant criteria were defined as part of these regulative frameworks. The frameworks also served to

define some minimal requirements on safety and sustainability that a product should meet. In the cases of radical design, the lightweight car and the lightweight composite trailer, decisions with respect to ethically relevant issues were made primarily on the basis of internal design team norms.

Three further observations can be made. One, in the cases of normal design, the regulative framework did not cover all ethically relevant issues. The engineers or their customers had to make some ethically relevant decisions that went beyond the existing framework, for example which accident scenarios to take into account in the design of piping and pressure equipment. Two, sometimes the regulative framework was not deemed relevant in a design process because the design engineers believed that taking into account these frameworks was outside their specific responsibility as design engineers. In the bridge case (normal design), the engineers did not consider the framework related to work conditions. In the trailer case (radical design), the engineers took into account only part of the framework on trailers. Three, with respect to radical design, even if internal design team norms played a predominant part in ethically relevant decisions made during a radical design process, regulative frameworks still played a role, in the sense that the values, like safety and sustainability, contained in regulative frameworks were still considered to be very important.<sup>9</sup>

The cases reveal a number of reasons why regulative frameworks are not, or not entirely, applied in radical design. One reason is that frameworks cannot be applied because application sometimes leads to recommendations that are, from a technical point of view, senseless. In the case studies, the inapplicability of existing frameworks was partly due to the use of new materials. Some concepts in a regulative framework lose their applicability if another material is used. For example, when a design that is usually made in homogeneous metals is made in composite materials some of the material properties cannot be determined in the ways prescribed by the relevant framework. With composite materials stresses will vary in the different parts constituting the composite. The notion “the stress in the material” as stated in current regulative frameworks loses its meaning because the different parts of a composite will be subjected to different stresses and speaking of “*the* stress in the material” thus becomes meaningless. The consequence of this is that all guidelines and calculation rules referring to stresses will be inapplicable for a product made in a composite.

Earlier, we defined a regulative framework as the set of rules and norms that applies to a class of technical products with the same function. However, as the composite example shows, some of the rules and norms of a regulative framework are specific for a certain material. Some rules may also be specific for a certain hardware configuration or an operational principle. Conversely, other rules or norms, like the need to take into account safety considerations, are so general that they are still applicable and relevant for products made of a different material, or

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<sup>9</sup>Note that in the trailer case the engineers thought that safety was important but they defined safety very narrowly as structural reliability.