# Deciding on Ethical Issues in Engineering Design

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**Abstract** Engineers make decisions concerning ethical issues like safety and sustainability in design processes. We argue that the way in which engineers deal with such ethical issues depends on the kind of design process they carry out. Vincenti distinguishes between normal and radical design. In normal design processes the operational principle and normal configuration are given, in radical design processes they are not given. We present four case-studies of actual design processes: two processes of normal design and two of radical design. We show that in the normal design processes, engineers use what we call regulative frameworks to make ethical decisions. Regulative frameworks consist of legislation and technical standards, and interpretations thereof by certifying organizations. Operationalizations of ethical criteria are given in these regulative frameworks. Regulative frameworks also define some minimal requirements on safety and sustainability that the product should meet. In the radical design processes, such frameworks are absent or difficult to apply. Morally warranted trust in engineers can therefore not be based on regulative frameworks in the case of radical design; for radical design a different basis is needed on which to base such trust.

## 1 Introduction

Engineering design is fraught with the need to make ethically relevant choices. Suppose, for example, that you are designing a printer/copier. During the design process, a choice will be made as to whether the printer/copier will be able to print two sided or not. Once a choice is made for two sided printing and copying, an additional choice needs to be made about the default properties. If two sided printing is the default option, users have to make an explicit choice to print one sided. This default option will probably save a lot of paper compared with a printer/copier that can only print on one side. While the environmental effects of saving paper by

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printing two sided copies for a single printer/copier are limited, the global effects for the total number of printers/copiers in use is enormous. As paper is produced from wood, a reduction in paper use will also reduce the amount of wood used. The production of paper, the transportation of wood and the transportation of paper all require energy. The amount of energy used in the process will also be reduced and the total reduction in resources used will be significant on a global scale.

This example shows that decisions made during the design phase of a product, that might seem trivial during that phase, can have large environmental effects. Such environmental effects are ethically relevant because protecting the environment and sustainability are moral issues. Looking at sustainability questions such as: what is our responsibility towards future generations? and do ecosystems have intrinsic value? need to be answered. When engineers make decisions about sustainability during a design process they implicitly take a stance on these issues. For example if the one sided option is chosen for the printer/copier then future generations will probably have to deal with more environmental problems because more (fossil) energy and trees have been used.

We will call certain issues ethical if moral values are at stake. The central moral values we focus on in this contribution are safety and sustainability. In the case of the printer/copier, the moral value of sustainability seems to require unequivocally the choice for a device for which two sided printing is the default option. Often, however, moral values will come into conflict during a design process: the option that is the safest for example, might not be the most sustainable one (cf. Van de Poel, 2001; Van Gorp and Van de Poel, 2001). In such cases, trade-offs between different moral values have to be made. How to make such trade-offs in an acceptable way is in itself an ethical issue.

In this paper, we argue that there is an important difference in the way engineers deal with ethical issues in normal and radical design processes.[1] More specifically, our claim is that engineers use regulative frameworks to decide on ethical issues in normal design, while in radical design processes such frameworks are absent or inapplicable. To substantiate this claim, we present four case studies of design processes: two normal and two radical. The two normal design processes were one, designing piping and equipment for the chemical industry and two, designing a bridge. The two radical design processes were one, designing a sustainable lightweight car and two, designing a lightweight trailer to transport sand. These case studies were carried out by one of the authors (Van Gorp, 2005). The methods used for data collection included observing design teams, reading design documents and interviewing engineers.

In the following section we will present Vincenti's distinction between normal and radical design and introduce the notion of a regulative framework. Descriptions of the four case studies are given in section three. We end the paper with a discussion and conclusions including the moral implications of the results.

[1] See Van de Poel and Van Gorp (2006) for a comparable claim. The claim we make here is more specific, and we present some new cases.

## 2 Design Type and Regulative Framework

### *2.1 Design Type: Normal Versus Radical Design*

Vincenti (1990; 1992) uses two dimensions to characterize design processes: design hierarchy and design type. Here we focus on design type because earlier research suggests that this is important for how engineers deal with ethical issues (Van de Poel and Van Gorp, 2006). Vincenti (1990) uses the terms "operational principle" and "normal configuration" to indicate what normal design as opposed to radical design is. "Operational principle" is a term introduced by Polanyi (1962). It refers to how a device works. For example, incandescent light bulbs and fluorescent lights have different operational principles. In a light bulb a tungsten wire conducts the electrical current. This heats up the wire: electrons are excited and emit light as they fall back. In fluorescent lights a large voltage passed between two electrodes travels through a gas creating a kind of plasma. Electrons from mercury atoms in the tube are excited and emit ultraviolet light. Phosphorus powder on the glass transfers the ultraviolet into visible light by electrons being excited and emitting light in the visible range when falling back. So although both types of lights give light they have different operational principles.

Normal configuration is described by Vincenti as: '… the general shape and arrangement that are commonly agreed to best embody the operational principle.' (1990, 209). We interpret the general shape and arrangement to include the kind of material that is used. Vincenti does not include the materials explicitly but the materials used in a design are very important for the shape of parts and the product. Moreover, using different materials, for example plastics instead of steel, often requires new types of knowledge to produce a product and new methods to test it. The use of such new knowledge and methods is typical for radical design compared to normal design.

According to Vincenti's definition, in normal design both the operational principle and normal configuration are kept the same as in previous designs. In radical design, the operational principle and/or normal configuration are unknown or a decision has been made not to use the conventional operational principle and/or normal configuration.

### *2.2 Regulative Framework*

For most products, a system of regulations and formal rules exists that can be used to govern design decisions, including decisions on ethical issues like safety and sustainability. Van Gorp (2005) has introduced the term regulative framework for the system of norms and rules that applies to a class of technical products with a specific function. A regulative framework consists of all relevant regulation, national and international legislation, technical standards and rules for controlling and certifying products.[2] A regulative framework is socially sanctioned, for example by a national or supra-national parliament such as the European parliament or by organizations that approve standards. Besides the technical standards and legislation, interpretations of legislation and technical standards also form part of the regulative framework. Interpretations of standards and legislation can be provided by the controlling and certifying organizations and by engineering societies for example, during the courses they organize for engineers on state of the art design practices. Informal rules and company-specific rules are not part of the regulative framework.

There are various EU directives for a broad range of products.[3] This includes for example the Directive Machinery 98/37/EC, which covers all machinery with moving parts. Another important directive is the Low Voltage Equipment Directive 73/23/EC, which covers all equipment with a voltage between 50 and 1000 DC and 75 and 1500 AC.

EU directives have to be implemented in national law within the EU. It is, therefore, to be expected that all EU countries will have national laws implementing the EU directives. All these directives refer to technical standards such as the EU codes.[4] If these standards, or national standards if the EU codes are not available yet, are followed in design processes, then compliance with the directive is assumed. The European Committee for Standardization (CEN) is responsible for formulating the standards. CEN has committees for formulating standards on subjects ranging from chemistry, to food, consumer products, construction, transport and packaging (www.cenorm.be).[5]

[2] In Van de Poel and Van Gorp (2006) we use the concept ‘normative framework’ introduced by Grunwald (2000; 2001). The normative framework is different from the regulative framework because the normative framework has to meet certain normative criteria.

[3] The main goal of standardization in the EU is to ensure a free market and to remove technical barriers for trade within the EU (European Committee, 1999). Besides the goal of supporting a free market, standardization ‘promotes safety, allows interoperability of products, systems and services, and promotes common technical understanding’ (www.cenorm.be).

[4] In the US, the following terminological distinction is often made between codes and standards: codes are legal requirements that are enforced by a governmental body to protect safety, health and other relevant values; standards are not mandatory; they are usually regarded as recommendations (Hunter, 1997). EU codes are not legally enforced. If EU codes have been applied the design is assumed to comply with the relevant directive. In the mentioned US terminology, EU codes are therefore technical standards.

[5] A full description of the cases can be found in Van Gorp (2005).

# 3 Case-Studies

## *3.1 Piping and Equipment*

The studied design process for pipes and pressure vessels for chemical plants was a case of normal design: the operational principles and normal configurations were known and used.

After disasters like Bhopal, Seveso and recently the severe contamination of a Chinese river with benzene following an explosion in a chemical installation, it is not difficult to support the idea that safety in chemical installations is an ethical issue. In the case studied, the decisions regarding safety that engineers made during the design process ranged from decisions about safety valves, load scenarios, required material properties, to safety distances between pressure vessels. The engineers used the existing regulative framework to help them make decisions concerning safety, and believed that designing according to the regulative framework produced safe installations.

The regulative framework for pipes and pressure vessels used in the Netherlands is based on the European Pressure Equipment Directive (PED) (European directive 97/23/EC). Certification organizations, called Notified Bodies, are appointed in each EU country to check whether new designs and refurbishments comply with PED regulations. Approved designs obtain a CE mark.

Other regulations that are part of the regulative framework are those encompassing environmental regulations and regulations regarding noise and smell. Such regulations are commonly used to regulate the outcome of the design process: an installation should perform within the limits of allowed noise levels and emissions.

The relevant legislation and regulations make references to standards, which are therefore also part of the regulative framework. The organizations that formulate standards differ in different countries. Standards can be formulated by professional organizations, e.g., the American Society of Mechanical Engineers (ASME), industry, e.g., *Regels* in the Netherlands or by governmental institutions, e.g., British Standards. Standards are usually written rules for good design practice that, if used correctly, should protect the health and safety of persons and protect the environment. Standards are often prescriptive; they prescribe the use of certain hardware and calculations. In some countries, the application of a certain standards is required by law. In many states of the United States, the application of the ASME standards for pressure vessels and piping is required by law. In the EU, the use of EU standards during the design process of pipelines and pressure vessels leads to an assumption that the design conforms to the PED.

Despite the existence of an extensive regulative framework for pipes and pressurize vessels some elements of choice remain for the design engineers and for their customers. Due to the existence of a variety of safety standards for pipes and pressurize vessels the design engineers and their customers need to choose which of the standards to apply. Additionally the regulative framework does not cover all the safety choices that need to be made during the early phases of the design process. Where such choices are not mandated safety becomes the responsibility of the design engineers and their customers. For example, the design engineers in the case study mentioned that accident and load scenarios are not defined in the European standards and legislation for pipes and pressure vessels, even if the PED requires that a risk analysis is carried out. According to the engineers they usually referred to company standards for load and accident scenarios in such cases, or, if these are not available, discussed the issue with their customer or asked advice from the national notified body.

### *3.2 Bridge*

Our second case concerned the preliminary construction design phase for an arched bridge over the Amsterdam-Rijncanal in Amsterdam. This case was an instance of normal design because the operational principle and normal configuration of arched bridges are well-known and were used when designing this bridge.

Several ethical questions about the safety and sustainability of the bridge were encountered by the engineers. The collapse of a bridge can cause deaths and injuries so decisions that influence the chances of the bridge collapsing are ethically relevant. Moreover, the construction industry is prone to accidents in which people are killed or seriously injured on the construction site, and the Netherlands is no exception. During the design process of a bridge decisions are made that influence construction site safety and risks that workers face during construction. Safety of the bridge covered several different aspects: safety during use, safety during construction, and safety for ships passing under the bridge.[6]

Most of the decisions concerning safety during use of the bridge were made using a regulative framework for bridge building that is based on the Dutch building decree. The building decree is detailed and contains prescriptions for, for example, strength calculations. The building decree refers to standards, for example, the Dutch standard for concrete and steel bridges (NEN 6723, 1995 and NEN 6788, 1995, respectively). Although the bridge regulative framework covers most of the decisions that need to be made concerning bridge safety and sustainability of the construction, it does not cover all decisions. An example of a safety issue that is not covered is misuse. In the case of the Amsterdam bridge people could climb onto the arches of the bridge because the arches were not very steep. The design engineers had to decide whether or not to do something to prevent people from climbing onto and walking on the bridge arches.

The regulative framework concerning safety during bridge construction is based on two European directives: 89/391/EC (working conditions) and 92/57/EC (health and safety on construction sites). The European directives are incorporated in

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[6] We will not focus on obstructing ships on the canal, an elaboration of this can be found in Van Gorp (2005).

Dutch legislation in the working conditions decree (Arbeidsomstandighedenbesluit version February 2004). This decree requires a health and safety plan to be made for the construction of a bridge, and the design engineers, contractors and customers are held responsible for different parts of the health and safety plan. During the design phase, a design health and safety coordinator has to list and evaluate all risks. There are more substantial rules for working conditions but the design team did not know the exact content of these rules. They believed that compliance with these substantial rules was part of the responsibilities of the contractor, because the contractor is the employer at the building site. In fact, compliance to the rules is the responsibility of the employer and the employee in the working conditions decree. Thus there is a regulative framework for working conditions but this regulative framework was not used during the design process because the design engineers did not consider it part of their responsibility to address working condition issues arising during construction in any substantive way. The engineers only made the required list of risks during construction.

### *3.3 Lightweight Car*

The DutchEVO, a very light, sustainable family city car was designed at Delft University of Technology. The empty weight of the car was set at a maximum of 400 kg. At present European family cars usually weigh about 1200 kg; even the two seater Smart has an empty mass of 720 kg. The design requirement to produce a sustainable car with an empty mass of less than 400 kg led to a radical design process. It was not certain whether the normal configuration for a car could be used; this was something that had to be decided on during the design process. Eventually, a standard engine was chosen but the floor structure, the side panels and the doors were very different from those of regular cars.

Ethical issues related to safety and sustainability were encountered by the design engineers. First, the light car will always have higher acceleration in a crash with a heavier car and is, therefore, less safe than the heavier car for people inside the car. Second, it is not possible to incorporate all usual active and passive safety systems in a car of 400 kg. With regard to car safety the tests performed by EuroNCAP[7] are an important element of the regulative framework concerning cars in the EU. However, it was not possible to design a light car and still aim at very good results on the EuroNCAP crash tests. After an analysis of these crash tests, the design team decided that these crash tests lead to heavy cars that make people feel safe in their car. Cars performing well in EuroNCAP tests do not necessarily protect people well in all kinds of crashes, for example in crashes into trees or lampposts. Therefore the design team rejected the EuroNCAP crash tests. Third, the design team based part of their ideas about sustainability on the Brundtland definition of sustainable

[7] EuroNCAP is a cooperative of different European consumer and governmental organizations.

development, i.e., "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987, 43). However, it is unclear whether cars can be considered to be sustainable under this definition. The Brundtland definition is usually interpreted as referring to basic needs only, and the question is whether personal transportation is a basic need of people. Fourth, sustainability was operationalized mainly as using less energy by making the car lightweight but other operationalizations can also be defended, for example, that a sustainable car is a recyclable car. Fifth, the design team also wanted the car to be "emotionally sustainable". By this they meant that people should get more satisfaction from the car than merely being able to use it to go from A to B. The team wanted to stimulate a caring relationship between car and owner, to promote long-term ownership rather than people 'throwing away' their car after a few years, and they wanted the car to be fun to drive. This can be at odds with the other part of sustainability because if people really like to drive a car, then they might use the car for distances that they would normally walk or cycle. This would increase energy use no matter how light the car is.

Decisions about safety and sustainability were made based on internal design team norms. These norms were developed during the design process. An example of an internal design norm was that when choosing between different options the lighter option should be chosen. Another internal design team norm was that for making driving in traffic safe, the driver of the car should feel a little vulnerable. These internal design team norms were based on the education of the engineers in the design team, their previous design experience[8] and their personal experience. The norm that the car should make the driver feel a little vulnerable was based on the personal experience of design team members that they tended to take more risks in modern cars than for example in a Citroën 2Cheveux.

## *3.4 Trailer*

The second radical design case study was a preliminary design and feasibility study for a light composite trailer with a new loading/unloading system. This was a radical design process: the normal configuration and operational principle were changed because a new loading/unloading system was included in the design and a composite material was used to meet the demand for a light trailer.

An important ethical issue in trailer design is safety. In this case, a safe trailer was operationalized by the design engineers as a structurally reliable trailer: this means a trailer that will not fail during use. When designing a "normal" trailer there is a regulative framework that can be used that incorporates rules on maximum

[8] Most of the design team members were bachelor, master and graduate students therefore their design experience was very limited. The project leader was an experienced car designer and two other more experienced designers worked for the project.

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.[9]

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 loose 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 looses 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

[9] Note that in the trailer case the engineers thought that safety was important but they defined safety very narrowly as structural reliability.

with a different normal configuration or operational principle. So while parts of a regulative framework often become inapplicable in radical design, other parts may still be applicable and relevant.

Another reason why existing regulative frameworks were not used in the radical design cases, especially in the lightweight car case, was that the engineers rejected, for moral reasons, parts of the framework in particular the EuroNCAP crash tests. These crash tests were considered morally inadequate because they stress the safety of people inside the car at the cost of sustainability and the fuel efficiency of a car. Note that in this kind of situation, the causal arrow can be reversed. Considering a regulative framework at the start of the design process can cause design engineers to reject parts of it and to develop a more radical design.

It is likely that the differences between how ethical issues are dealt with in normal and radical design holds beyond the four case studies presented here. Regulative frameworks exist for most products. The use of such frameworks can be required by law, or, if that is not the case, following the framework is often interpreted as compliance with the requirements of the law.[10] This legal or semi-legal status of regulative frameworks is clearly a strong incentive to use such frameworks to make ethically relevant choices in design.

In radical design, however, regulative frameworks often become partly inapplicable. In our case studies we found one particular reason for this to happen: the use of another type of material. One might expect, that a design that is either based on a new operational principle or a new normal configuration, or both, will often cause parts of an existing regulative framework to become inapplicable. However, in general, the general goals of a regulative framework, like safety, will still be relevant in the case of radical design. Yet specific operationalizations or prescriptions designed to promote safety will often become inapplicable or contradictory. For example, designing an automatically guided vehicle using the existing regulative framework on traffic would lead to contradictions and strange situations. In the current regulative framework pertaining to traffic safety a vehicle should always have a driver but the goal of designing an automatically guided vehicle is to design a vehicle that can move safely without a driver.[11] One goal of the traffic safety regulative framework is to achieve safe vehicles and safe traffic flows and this higher level goal is still relevant for the design of automatically guided vehicles. So the rationale behind the regulative framework remains important but most of the legislation and standards contained in the traffic regulative framework will not be applicable in the case of an automatically guided vehicle.

If a design team or a customer rejects, parts of, a regulative framework because they think that the regulative framework leads to morally unacceptable products, this can lead to the rethinking of normal configurations and operational principles.

[10] The latter leaves open the possibility to meet the law by other means than following the regulative framework.

[11] Because Dutch legislation requires vehicles in public space to have a driver, special social arrangements need to be made to carry out tests with automatically guided vehicles.

Some more detailed and prescriptive parts of regulative frameworks are formulated with certain operational principles and normal configurations in mind. If a design team thinks that these parts lead to morally unacceptable products, then they will rethink the normal configurations and operational principles as was done in the lightweight car case. Rejecting, parts of, regulative frameworks can lead to the design process becoming radical.

From the foregoing it can be concluded that even if a regulative framework is available to guide, parts of, a radical design process, it will be rejected or not be, completely, applicable. This would mean that, in general, a regulative framework cannot, or can only be partly, used in radical designs to help design engineers decide on ethical issues. Engineers in these circumstances will, in general, refer more to internal design team norms. If such norms do not exist, then norms will be developed during the design process. The design team members will use their field of education, design experience and personal experience to develop such internal design team norms.

We want to end our contribution by briefly sketching the moral relevance of our findings. Some engineers maintain that technology is morally neutral and that no ethical decisions are made during design. We have provided ample (empirical) evidence why this position is mistaken. Nevertheless, the distinction between normal and radical design is relevant for how moral considerations are taken into account during design. In normal design, moral considerations are embedded in the regulative frameworks that are used for making ethically relevant considerations. Such moral considerations are introduced during the formulation, and reformulation, of such regulative frameworks at the level of the engineering community and society. So even if individual design engineers are unaware of the moral issues in their design process, or are not inclined to take into account moral considerations, such considerations enter the design process through existing regulative frameworks. This mechanism is absent in the case of radical design. Therefore, whether and how moral considerations are taken into account depends to a large degree on the design engineers themselves. The moral responsibility of the design engineers for the products they design, as a result, becomes larger (cf. Van de Poel and Van Gorp, 2006). Sometimes, this might mean that relevant ethical issues are neglected, as with respect to traffic safety in the trailer case. Conversely, it might also lead to more attention for moral issues than found in normal design. In the lightweight car case, for example, the design engineers chose a radical design at least partly on moral grounds.

The distinction between normal and radical design is also relevant for the grounds on which the public can have morally warranted trust in the work of engineers and the resulting products (Van Gorp, 2005). Regulative frameworks are usually socially sanctioned; they are the result of recognized and socially legitimatized processes of decision-making. Therefore, such frameworks can provide grounds for morally warranted trust in engineering and in technical products. In radical design, this basis for trust is lacking. This raises the question of what the trust placed in engineers by the rest of society can be based on in such situations. We will not try to answer this question in detail here, but we will mention one possibility: in such situations trust might require engineers to take into account different possible perspectives and thus to look beyond their internal design team norms (Van Gorp, 2005).

Although it might seem to follow that in general radical design is morally more dubious than normal design, radical design can be morally warranted in situations where good reasons exist to doubt the moral adequacy of a current regulative framework. Take the case of crash safety regulations for example; at present these tend to focus on people inside the car, paying little attention to other unprotected road and pavement users such as cyclists and pedestrians (cf. Van Gorp, 2005).[12]

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