"Things That Went Well – No Serious Injuries or Deaths": Ethical Reasoning in a Normal Engineering Design Process

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ABSTRACT: *We argue that considering only a few 'big' ethical decisions in any engineering design process – both in education and practice – only reinforces the mistaken idea of engineering design as a series of independent sub-problems. Using data collected in engineering design organisations over a seven year period, we show how an ethical component to engineering decisions is much more pervasive. We distinguish three types of ethical justification for engineering decisions: (1) consequential, (2) deontological or non-consequential, and (3) virtue-based. We find that although there is some evidence for engineering designers as 'classic' consequentialists, a more egocentric consequentialism would appear more fitting. We also explain how the idea of a 'folk ethics' – a justification in the second category that consciously weighs one thing with another – fits with the idea of the engineering design process as social negotiation rather than as technological progress.*

Introduction

The title of our paper is a quote from an actual company report evaluating a then recently concluded design process. It gives a contradictory message. The fact that something morally bad *didn't* happen is seen as a reason to give a *positive* evaluation of the foregoing design process. The quote rather gives the impression of a lucky escape. Maybe injuries and deaths had been expected at the beginning of the process, and fortunately didn't occur. The suggestion is that, in everyday situations, engineers are making moral and ethical decisions based on little more than what we might call

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'intuition' and fortune. This raises an important question. If we are to assume that there is some sort of ethical aspect to everyday engineering design activity, and further that these aspects could have important consequences (in avoiding 'serious injuries or deaths' for example), then we should know just how engineers make ethical decisions in everyday situations. Davis[1] lists five questions that he feels engineering ethics research should address, two of which the present paper addresses: "What do engineers *do*?" and "*How* are engineering decisions made?" (italics Davis'). One would think that there was relatively good agreement about these issues, and within the engineering profession itself there is. However, when these questions are cast ethically, there has been remarkably little progress. Less than 1% of papers at the last two International Conferences on Engineering Design[2,3] were specifically to do with ethics.

This paper first discusses literature that characterises both the nature of engineering designing and engineering design ethics, concluding that the design process represented as a combination of sub-problems, of which ethics forms one, is inappropriate. It then goes on to argue for an integrated view of engineering designing in which ethics can play a fundamental role in decision making. To illustrate how this might work in practice we attempt to determine how a range of ethical theories – consequentialist, non-consequentialist, and character-based – might fit ethnographic data collected from engineering design practice in a series of studies that have taken place over a seven year period. We provide evidence to show that an ethical component can be discerned in reasoning that might initially appear ethically neutral and also that a non-consequentialist framework can account for a large portion of these ethical components to reasoning. We conclude by suggesting that viewing engineering design as social organisation, rather than as technological progress, is a more profitable way of considering ethical aspects of decision making.

Ethics treated as a sub-problem of engineering design

It is commonplace in the field of engineering design methodology to conceptualise engineering design as a series of 'sub' problems which, when solved and re-combined or synthesised, go to make a final designed object. In what has become a canonical text in engineering design, Pahl and Beitz[4] note that 'an overall function can often be divided directly into identifiable sub-functions corresponding to sub-tasks. The relationship between sub-functions and overall function is very often governed by certain constraints, inasmuch as some sub-functions have to be satisfied before others'.[4 (p.31)] Pugh[5] comments that 'a conceptual design may be defined as that which represents the whole or totality of the projected artefact… in other words, it represents the sum of all of the subsystems and of the component parts which go to make up the whole system'.[5 (p.68)] This thinking about design problems can be traced back to the 'design methods' movement of the 1960s. Alexander's *Notes on the Synthesis of Form*[6] observes: 'a program really gives us a series of simpler sub-problems, and tells us in what order to solve them… if we can learn to draw the gross structural components of the problem the difficulty will disappear'.[6 (pp 116-117)]

There are good reasons for thinking about engineering design in this fashion, but for complex engineering objects involving thousands of man hours the 'sub-problem' approach tends to create areas of specialisation, which in turn concentrate on very specific aspects of the design: marketing for example, or aesthetics, electronics, testing, mechanics, and ergonomics.

Current approaches to teaching engineering design ethics have done nothing to improve this situation, instead introducing yet another sub-problem: ethics. This is because engineering ethics is largely taught using case studies which naturally focus on 'big decisions'.[7,8,9] Did the Morton Thiokol engineers do enough to avert the *Challenger* disaster?[10] Should William LeMessurier have gone public?[11] The very fact that there is a case to discuss at all usually means that something bad has happened or just been avoided. But an engineering design process, even one with a morally bad outcome, is not just one ethical situation, it is – by its very nature as a process – a long sequence of decisions, not necessarily separable from each other. In forensic studies of engineering design processes resulting in product failure Hales[12] notes that it is usually a sequence of accumulating decisions and misunderstandings that lead to a bad outcome, not just one 'big decision'. This implies that, ethically speaking, engineering design might be better thought of as a process of accumulating micro-ethical decisions, rather than a small number of *explicitly* ethical decisions. Although it is possible for engineers to find themselves in an explicitly ethical situation, it is more likely that ethical decision-making is infused with other forms of decision-making in engineering designing.

It is the idea of ethics as a sub-problem of an ongoing design process that we are questioning here. The idea that, at some point in an engineering design project, the project leader might assign an 'ethics manager' to make sure that all ethically questionable implications of the design have been adequately addressed. While seemingly plausible as an idea, this sub-problem approach, in assigning 'ethical aspects' to a third person affects to remove something which cannot be removed; the ethical responsibility of the engineering designers involved in the project. The problems with this approach can be illustrated with an example. Davis, establishing a basis for his study of engineers and managers[13] writes: 'we begin with the assumption that whenever an engineer faces an ethical problem, something has gone wrong'. This assumption, criticised elsewhere,[14] pre-supposes a 'sub-problem' view of designing. The 'something' in question being a resolutely ethical 'something'. The possibility that an engineer can be faced with an ethical problem without realising it, especially if it runs together with other issues in the design process is, wrongly in our view, disregarded. According to this view, things are either 'right'; and hence not an issue; or 'wrong', and an ethical issue to be addressed.

Why is ethics viewed as a sub-problem inappropriate? The answer lies in the integrated nature of decision-making in designing. Scruton, discussing methodologies of designing that aim at giving optimal solutions to design problems through decomposition into smaller problems[15] suggests that the approach is fundamentally flawed: 'in every serious task there are factors which, while of the greatest importance, cannot be assigned a relative value – not because their value is absolute, but because a

man (sic) may not be able to judge in advance just when he is prepared to tolerate their remaining unsatisfied'.[15 (p.29)] One cannot know in advance whether the solution will be acceptable or not, because one cannot second guess what the response to the solution will be. This response is derived from the intuition of the designer (whatever that might be) who can only then give reasons for or against the design solution. Vincenti's discussion of flying qualities[16] echoes Scruton: '*for the designer*, the quantities set down in performance specifications are themselves *objective ends*; the quantities prescribed in specifications of flying qualities are *objective means* to an associated *subjective end*' (italics Vincenti).[16(p.100)] Simon[17] expresses similar concerns somewhat differently by using the analogy of a papaya fruit. Without the knowledge of what a papaya fruit will taste like, we can't know how we will be able to 'use' this taste in future experience. The result of biting into the fruit, and the discovery of its taste, necessarily evokes what he terms 'a new dimension of utility'. This, according to Simon, is the nature of decision making in the design process where outcomes are uncertain. The reasons for a design solution, then, only occur *post hoc*, in judgements about an existing solution. It is commonly thought that these judgements of value must somehow be aesthetic (judgements of preference), but we see no reason why they can't also be ethical. It is the purpose of this paper to explore the idea of an ethical component to reasoning, in particular evaluative reasoning, in the engineering design process.

Ethical aspects of conversation during the design process

Such a proposition has a number of consequences for subsequent study. Firstly, the study should be focused at the level of normal engineering design conversation, where judgements are typically expressed and discussed. In theory it should not matter which conversation in particular will form the basis of any analysis, since we are suggesting that ethical components of judgements are prevalent within engineering design. Herkert[18] refers to a 'microethical' approach to engineering ethics, and this is something of what we have in mind here. There have been studies of ethical decision-making in everyday situations within the field of philosophical psychology[19] though few in what might be considered a 'normal' engineering design process. Davis[13] offers some insight into the normal practice of engineering designers using a questionaire methodology, though this could hardly be considered a microethical approach.

Secondly, such a detailed inquiry needs to have some way of distinguishing what form an ethical component of evaluative reasoning might take. Clearly we are looking for something like imperatives or justifications in relation to certain judgements being made within engineering discussion. To distinguish these types of imperatives and justifications we have chosen a classification corresponding to three ethical frameworks. Firstly, consequentialist: the idea that engineering acts are justified by their consequences. Secondly, deontological or non-consequentialist: the idea that the ethical quality of an engineering act is derived from something other than the consequences of the act, by the notion of duty for example. Thirdly, virtue (character-based) ethics – the idea that the good character of the actor is more important than the

ethical nature of a particular act. Obviously there are overlaps here. One could argue that looking for 'character' as a justification is essentially looking at consequences, but our intention is simply to have three primary focuses with which to parse empirical data.

As an initial hypothesis for the inquiry there are strong arguments for considering ethical engineering design judgements within a broadly consequentialist framework. Firstly, we have already remarked that discussion in engineering ethics is largely based on the outcome of the process: the products that are produced. Secondly, engineering design as a profession aims specifically to change the world in some respect – generally considered to being directed towards making the quality of people's lives good, i.e. better, more efficient, and more effective – and this means it is directly concerned with consequences (or teleology). Finally, one can see – if one traces a design process backwards as forensic studies of the design process have[12] – a clear link between outcomes and the decisions resulting in those outcomes. The final point does, however, raise the question about the validity of looking backwards from the end product to (re)construct the decision-making of the process.[20] Such an approach tends to ignore decisions that turned out not to be significant. During the process itself a designer is not in a position to know whether a certain decision will increase or decrease in significance in relation to the final designed product. The last point notwithstanding, it seems plausible to suggest that design engineers reason in ways befitting a consequentialist ethical framework when they design.

Method

Over the past seven years the authors have conducted a number of studies looking at various aspects of the engineering design process; particularly types of social behaviour[21] and decision making.[22] Sometimes this has been carried out with the use of interviews, other times by direct observation or attendance at design meetings. In all studies detailed transcripts, often in verbatim form, have been produced. In total we have a body of data consisting of around 100 detailed interviews and 150 hours of observation and participation in meetings. These data have been collected with the intention of studying something other than ethical reasoning. However, because the data is focused on the actual practice of engineering design, we feel it is highly suitable for the purpose of looking at ethical reasoning in the design process.

The first phase of the analysis looked through some key transcripts from the data – transcripts involving meetings or direct workplace conversation – and isolated instances where ethics seemed to have played a role in reasoning. The second phase was to assign these instances, through discussion, to one of the three ethical frameworks described in the previous section: consequentialism, non-consequentialism, or virtue ethics. The final phase of our analysis then sought, in an inductive fashion, to make distinctions within the three broad categories before bringing everything together in a tentative theory of ethical reasoning in engineering design. We should stress here that this is not an anecdotal approach. The instances we have identified in our data derive from actual conversation, not second-hand reporting

(leaving open the question of designers who tell each other anecdotes about past experiences within a conversational situation). Where we have used second-hand reporting as evidence, we have made this clear in the following text. To a large extent we have followed the method of Bucciarelli[23] which could be summarised as: recording, thinking, explaining.

Results

Consequentialist reasoning in designing

There was some evidence of consequentialist reasoning in our data. This was expressed in phrases such as: “we ought to be getting a machine better than we’ve currently got” or someone asking about a design: “so what are the benefits then?” This is a belief that engineering design should be progressing in some respect, making things ‘better’ for all parties concerned; the further implication is that ‘better’ things cause people to be ‘happier’ in some respect. One designer commented on a design: “it’s not going to be perfect, but it could be slightly better.” However, things can only be better when compared to what already exists, and engineering design practice brings with it a good deal of precedent.

Precedent provides a means of quickly using what has already been established in a particular design field. This can be embodied in several ways – in corporate standards, for example, or prior design projects, or simply as an existing idea within the design office. It is inevitable that future designs will be based on past designs and in our data there was much evidence to support this view. Designers would talk about “standard practice”, or say things like: “we’ve seen this system and it works” when deciding on a particular solution.

The idea that designers simply ‘re-use’ old designs might seem to conflict with engineers as basic consequentialists, but that doesn’t necessarily follow. A small improvement is still an improvement, and it is also an efficient design strategy. In this respect it is interesting to see what happens when adhering to precedent is used explicitly as an argument for *not* making things better. In one situation a client had requested some changes to what they saw as an insufficient design solution. In a discussion the company producing the solution decided that this request was unreasonable for two reasons. Firstly, that according to the client the company had been given the contract on the grounds that they were experts and so should just trust them. Secondly, that the solution offered conformed to ‘industry standard practice’, and so the clients could not expect any more.

This case is a counter-example to our ‘engineering designer as basic consequentialist’ argument since the designers have deliberately chosen not to maximise their client’s happiness through making the design ‘better’. A rather questionable business strategy, one might think, although clearly there are other factors in operation here (time and money to name two). In the following quote a manufacturing designer brings a number of these factors together: “we’re going round in circles now” he begins

> "It seems to me, the *simplest* solution is that system we've got out there – if it'll work – because N are *happier* with a mechanical system … it may be a *cheaper* option anyway." [italics ours].

What this shows is the combination of a number of factors in reasoning; a realisation that engineering design should be done *simply* coupled with a realisation that providing benefit (i.e. making the customer 'happier') always comes at some sort of cost.

The previous quote reveals another aspect of reasoning that takes place in designing, that many decisions are taken on the basis that there are a finite number of 'options' or 'alternatives'. Often designers asked each other something like: "what's the alternative?" or: "quite honestly there's three options." This illustrates a way of thinking both central to engineering design and crucial to ethical reasoning: asking *what if...?* questions. The 'what if…?' question ("what if there's a breakdown?") allows a quick mental simulation, and a quick assessment of the *consequences* of an alternative, particularly in terms of product function. One designer, consciously disagreeing with another said "I'm sure if you were to weigh that rig out there, the moving arc would be heavier." It is this focus on consequences that might provide some evidence that the consideration of alternatives in the design process is basically consequentialist reasoning. However this was not necessarily the case.

Aesthetic judgement in designing

One of the most striking things about our data was the fact that many decisions, given a range of alternative choices, seemed to be made more on intuitive aesthetic grounds than on a careful consideration of consequences. There is a subtle shift here between talking about consequences in objective terms, to talking about consequences in subjective terms. In the following example one designer complains about the design of a unit (booth) produced by another company. First of all he tries to argue on the basis of consequences: "if you get B+S to supply then all they'll do is weld up a tin box and it'll rot in a couple of years". A little later on in the same conversation, he says "the thing I don't like is that it's crude", an aesthetic justification. The conversation continues:

Designer 2 But it does the job…
Designer 1 No it doesn't, not laminar flow!
Designer 2 Yes it does…
Designer 1 OK, but it's a crap design, you wouldn't do it on a major booth would you?

The argument here is to achieve a solution with some sort of elegance. Such an approach was also evident elsewhere in the data with designers stating things such as: "there's none of this messing about … it's a simple operation, a two man job" and even

invoking their client's aesthetic taste in the negative evaluation of a solution: "It's got complicated maintenance access … DB don't like complicated things."

There were generally two aspects to these aesthetic judgements. The first was that things should be simple, but not too simple. The other was that things shouldn't be unnecessarily complicated. In many ways this is a principle of parsimony reminiscent of Occam's razor.[a] This is an important result because it would seem that many engineering designers like to think that most key decisions are based on objective information. While that is undoubtedly the case *sometimes* – we found much evidence to support what we termed the 'analytical norm' of engineering discussion; the 'objective' checking of figures in a social group for example – in a large number of cases decisions seemed to be being made at this largely intuitive, aesthetic level.[b] Sometimes this involved the aesthetic judgement of *consequences*, arguably a form of egocentric consequentialism, while at other times the aesthetic judgement was of existing solutions, where the reasoning seemed less about consequences, although still about right and wrong.

Non-consequential reasoning in designing

Mention of intuition takes us on to a consideration of non-consequential reasoning about actions in designing. The data did reveal what we came to term a 'folk ethics': a number of rules based on considerations like 'justice' or 'fairness'. Central to this folk ethics was the idea that two things should generally match each other. For example one designer, commenting on a client's propensity for adding things to a specification said: "well if they start adding stuff, they've got to pay", the idea here being that extra work is matched by increased money. A retributive variation of this basic 'you get what you pay for' ethic occurred when a designer commented on the poor performance of a supplier: "I think the sheer grief that S. have caused us, we should say: 'you ain't getting a penny'."

In a different vein we found variations of several well-known 'rules of thumb'. In a meeting discussing an ongoing design a designer said: "unless that's going to be brought up by J. there's no need to change it" a variation of 'if it isn't broken then don't fix it' (also termed *status quo bias*[19]). A design proposal quickly sent back by a client draws the comment "I didn't expect it to be rejected by you immediately" in a meeting, a variation on 'getting a fair hearing'. And so on and so forth. We found variations on: 'every cloud has a silver lining', 'don't put off until tomorrow what you can do today', 'do as you would be done by' and 'if you make your bed you've got to lie in it'.

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a. Entities should not be multiplied unnecessarily. Paul Wijdeveld[27] notes that, as an engineering designer, Wittgenstein also used the dictum: 'the design of fastenings, latches, and locks clearly imply a mechanical interpretation of Occam's Razor.'[17 (p.118)]

b. This issue is also discussed by Vincenti[16] in respect to the subjective feel of 'flying qualities' when related to the technical development of the aeroplane.

What draws these 'rules of thumb' together is the way that they equate one thing with another, revealing a sense of justice and fairness, features of a non-consequentialist ethics. Undoubtedly this folk ethics derives from the social contracts of the wider culture, but some of the rules seemed particularly suited to the 'trade-off' nature of designing problems. Bucciarelli, in his analysis of engineering designers,[23] states that engineers think in what he terms 'object worlds' – "worlds of technical specializations with their own dialects, systems of symbols, metaphors and models, instruments, and craft sensitivities". One feature of object world thinking, Bucciarelli maintains, is that 'the law of conservation applies, that is that nothing is destroyed only transformed'. The folk ethics that we observed generally supported this view.

The data also suggested another, more radical, way of conceptualising ethics within designing and that was to consider the design itself as a kind of person (and hence something that the designers could assign rights to, and feel obligations towards). The most obvious example of this was the 'design as baby' metaphor. Talking about a series of designs he had been involved with, a designer indicated: "this is the one I'm most proud of because it was the first" revealing a pride in the first born. Similarly two designers described the moment when they first received criticism about a design they had been working on as "difficult to take" because "it was our baby". A test product that had been received by a company was described as "dead on arrival" when it malfunctioned on power-up, while another designer in an interview spoke metaphorically about "the industry's love affair with radiant heating". Even when a designer says "the product has to be right" in arguing for a delay in delivery, the implication is that the design has to be 'developed' sufficiently; that is to say that every baby starts off unsure of itself, needs to be nurtured, fed, and looked after, but when it is sufficiently mature it will have to start living its own life.

This may seem a little far-fetched, but personifying an emerging design, one might argue, could play a vital part in ethical reasoning during designing. Essentially this process, known elsewhere as 'the pathetic fallacy', transfers some moral intuitions we have about babies, and people in general, on to a design. If designers talk in this way it becomes easier to use terms such as 'looking after the design' or 'nurture the design'. It allows designers to talk about responsibilities towards the emerging design. This mode of discussion is explained by Lakoff and Johnson[24] as 'allowing us to make sense of phenomena in the world in human terms [so that] we can understand on the basis of our own motivations, actions, and characteristics'. In designing it is an unconscious strategy that relates to non-consequential ethics because, as with a folk ethics it involves something we all tacitly understand: that we have duties and responsibilities towards other humans and, rightly or wrongly, particularly those humans that bear our hallmark.

Reasoning about virtue in designing

Up until now the sort of examples we have talked about rarely pertain to what one might think of as especially ethical issues. Rather they have concerned a more general ethics which encompasses things like 'the protestant work ethic' for example; a more

general way of behaving. This was the argument we suggested at the beginning of the paper when we referred to an accumulative 'microethical' approach. When talking about the idea of 'virtue' in designing, however, it was easier to identify a distinctly moral tone in many of the things that were said. This occurred particularly in the attribution of virtue to other people or organisations involved in the design process.

In analysing our data it was quite easy to list a number of declared or attributed virtues, most being fairly obvious but some surprising. In several interviews a strong attributed virtue that emerged was behaviour that emphasised collectivity, commonality, or collegiality. If a designer, through a particular action, had brought someone new into the design process, facilitated an agreement, or communicated some important information to a design team, it was attributed as virtuous behaviour. This would seem to illustrate the high value that is put on social agreement in designing. One might think that any behaviour that leads directly to people agreeing about something is 'progressing' the design process, taking it that little bit further towards its end; *adding* something.

Other attributed virtues tended to emphasise the negative characteristics of other parties contributing to the ongoing design process. In one meeting a designer revealed that: "I must admit M. are very much wanting to hide their position at the moment, they say 'look: our process maps on to [yours]'." The attributed virtue here is visibility; clearly the designer doesn't feel that M. are showing him either enough, or the right sort of, information for him to determine their position. The implication here is that sharing (the right sort of) information is good, while withholding information is bad. This was also confirmed in the interview data which showed the virtues of checking, consistency, objectivity, and emphasising evidence.

In a different context a designer, at a meeting to discuss a design for a rolling road that had been completed, but had sustained some damage in use, stated: "I think the attitude that we've all got to take is that it's the prats driving the cars… ." In referring to the operators of the new machine as 'prats' the designer is making a judgement about what he thinks is reasonable and appropriate behaviour, again an attribution of character which helps to bolster his argument that the damage sustained is not the fault of the producers. In this example reasonable and appropriate behaviour is seen as good, whilst unreasonable and inappropriate behaviour is seen as bad. Again this was confirmed in several interviews where the virtue of 'showing emotion' was seen as a weakness. For many engineers it would seem that the ability to coolly reason through a problem is of much higher value than displaying an 'emotional' reaction to something.

Another example of a negative evaluation of a company came when two companies (C. and S.) were scheduled to work with each other on site. S., according to a designer from C., had not behaved well: "…they got there at ten o'clock Saturday morning, by one o'clock they'd gone; they'd not spoken to the customer at all". Such behaviour had caused C. 'embarrassment'. There are two attributed virtues here, the first is 'hard work'; the designer from C. attributes insufficient work to S. – they showed up late and they left early. The second virtue is good communication; S. left the site without telling the customer what they'd done. Later on in the meeting, reporting on another problem, a site engineer reports: "we've tried; we've failed", the

professed virtue here being that of trying hard, even if it results in ultimate failure. Taken together the two separate examples illustrate the virtue of 'hard work' in the engineering design process. In some respects this could relate back to the folk ethics noted in the previous section, but there is an important difference. 'A good day's work' – a reformulated version of the protestant work ethic – implies no matching principle; there is nothing in return for 'a good days work' (although it *may* eventually lead to increased salary). For this reason it was felt to be more a judgment of character than a non-consequentialist ethical rule.

Discussion

Our working hypothesis for this study was that engineering designers are basically consequentialist when it comes to reasoning ethically. This, we argued, derives from the nature of the profession itself; making things better and more efficient for organisations and individuals and thus causing them increased happiness. The data suggested a slightly more sophisticated view favouring a subjective, rather than objective, view of consequences. There were a few clear instances of what one could call 'classic' consequentialist reasoning – explicitly arguing for a better product, for example, or wanting to make a customer happier. Where it became more difficult to judge was with 'what if…?' questions, a key element of engineering design thinking.[26] The way that engineering designers made intuitive aesthetic judgements about future situations in this context would seem more fitted to egocentric consequentialism. This came as a surprise to us since there are strong arguments for considering products in at least two of the companies in which we carried out studies, weapons and cigarette manufacture, as objectively unethical products. There were also few instances of any reasoning about the wider societal context for which the products were intended.

The extent to which what we termed a 'folk ethics' played a part in many decisions and discussions was also surprising. This is ironic considering the 'analytical norm' of engineering designers we noted, emphasising the virtues of checking, objectivity, and evidence (see also ref. 25). (Taken as a whole the engineering designers of our data certainly did not display the consistency they valued as a virtue.) However, there could be a good explanation for this. What we termed a folk ethics was based on sayings that explicitly balanced one quantity with another – 'you get what you pay for', for example. This sort of balancing makes sense when engineering design is seen less in the sense of 'technological progress', the sense in which we based our initial hypothesis on, and more in the sense of the engineering design process as social organisation. This is because social organisation suggests many different people, all, to some extent, having different goals. A balance must somehow be struck and it is possible that this need for balance can be found in a folk ethics where one quantity is specifically equated with another.

This highlights what we found when considering the evidence for virtue ethics in engineering design reasoning, particularly the virtue of collectivity; the idea that 'good' characters are the ones that emphasise sharing of information and working towards agreement. This, surely, must form the core of any theory of ethical reasoning in the

design process. If, as we have argued in the introduction, we can view engineering designing as a process that involves a series of micro-ethical decisions, then we can also view designing as a series of accumulating agreements. The range of these agreements obviously varies considerably; from the informal nodding of a head or the rhetorical use of 'we' implying unity in discussion,[26] to the formal recording of minutes and writing of specifications, contracts, standards and other documents. By considering the (ethical) reasoning leading to agreement it is possible to examine the often tacit and intuitive assumptions that go to make up a final design product. It is our contention that a better understanding of these tacit and intuitive assumptions can lead to a better understanding of ethics in the engineering design process.

One further question needs to be addressed. Have we really been talking about *ethics* in this paper? Much of the data we have quoted is not particularly about anything one would normally consider ethical (even if some of it has a moral tone); it is not even about 'typical' ethical concerns in engineering design such as safety. Our reply is that, although it is simply a fact that not much of engineering designing is specifically about what one might normally consider to be ethical issues, the products of an engineering design process – and particularly the use of those products – undoubtedly is. This makes it important to consider *any* example where reasoning and argument in a design process lead to an agreement being made and a decision taken. It is only when looking back, after things have turned out nasty, that reasoning apparently unrelated to ethics turned out to be ethical reasoning all along. We have simply been looking at design processes where, ethically speaking, nothing turned out nasty. And that happens to be the great majority of engineering design processes.

Conclusions

The analysis of ethics in engineering design often uses a case study approach, looking at the 'big' decisions leading up to engineering disasters. Such an approach reinforces a view of engineering design as the solution of sub-problems which both ignores the more pervasive influence of social agreement within the process and supposes that aims are quantifiable in advance of solutions being reached. We have argued in this paper for a more piecemeal approach, considering 'normal' situations and studying ethical assumptions at a micro level. We hypothesised that the ethical reasoning of engineering designers would concentrate on the consequences of design actions but our data suggested a more complicated account. We have shown that many judgements in the design process rely on what we have called a 'folk ethics' together with an intuitive aesthetic 'feel' for situations and solutions. In considering the virtue ethical aspects of design reasoning we showed how engineers attribute good and bad characteristics to other agents in the design process, but often contradicted these attributions in their own reasoning and behaviour.

It is the contention of the authors that a better understanding of assumptions that are often tacit and intuitive in engineering design decision-making would provide a firmer basis for thinking about ethics in the engineering design process. This also implies some form of ethical education other than case study material of 'big'

decisions. Perhaps some sort of reflective role-playing exercise could help to provide a more integrated approach to engineering ethics, the sort of forum that would allow students to question such things as motives while the open-ended process of design is actually unfolding, and the product of that process still indeterminate.[c]

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c. This 'open-ended' kind of approach to teaching engineering design is one suggested by Bucciarelli[28] in a more general context.

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