HOW GROUP VALUES DEGRADE ENGINEERING RATIONALITY

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summary

Engineers base their decisions on a variety of values. Rationality, the search for economically optimal solutions (within constraints) should have the upper hand, but practice shows that other group values reduce rationality. This is illustrated by a variety of examples, mostly obtained from experience in industrial projects. Here Max Scheler's 'value ethics' is too idealistic to provide a philosophical framework. Instead, a first step is made in the direction of realistic professional value ethics.

1. are engineers rational?

They have the reputation for behaving rationally. Presumably, in their personal contacts they do not differ significantly from other people, but emotions do not play a role in their technical decisions. At least, this is the common view.

> Many years ago the journal of the Royal Dutch Institute of Engineers set up an experiment. The majority of its readers received the usual objective advertisements, but others were sent some emotional versions instead. As a result, the latter received more attention than the former, which demonstrates that engineers are real human beings. The editors had, however, inserted one advertisement in *both* versions of the journal, which showed a young girl transporting a small drainage pump on her scooter, with the message: "I'll take it to Dad!" This proved to be a top scorer.

Of course, rationality does not exclude emotions. Although the industrial design of, for example, coffee machines, automobiles, and other consumer products increases costs, it makes sense from a marketing point of view. One topic of considerable importance is dealing with safety, health and reliability, which is, however, too complex and too important to include in this brief paper.

In daily engineering practice, rationality is often degraded by intersubjective values without the engineers being aware of the fact. We have experienced this while guiding student theses and directly participating in industrial projects.

2. value ethics

Comparing values is an important part of ethics. In this respect, we do not favor virtue ethics as propounded by Aristotle, duty ethics in line with Immanuel Kant, or appeal ethics in the spirit of Emmanuel Levinas[2]. Of course, all these approaches may play a role in engineering. For instance, in many designs the Greek search for the golden mean is reflected in the attainment of a compromise between contradictory factors. If Kant's categorical imperative ("Act only according to that maxim which can be generalized to a general law") is restricted to engineering, it can find application there too. The spontaneity of Levinas' ethics may make sense, for instance in cases where the potential contributions of design team members are ignored.

Value ethics, however, seems more suitable for application to engineering decisions, in particular because they reveal ideas that are more or less subconscious. The philosopher Max Scheler (1874-1928) developed value ethics. In line with the Jewish tradition, he saw ethics as the foundation for his concept of man. In this respect he made a distinction between 'ethos', 'practical morality ', and 'ethics': "One finds the real sphere of the ethical in 'ethos', i.e. the feeling and sensing of values, and their ranking by means of emotional acts, as put forward by a specific person or group." This comes very close to our topic, where 'group' is represented by engineers in a specific profession at a given moment of time.

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[1] The author is grateful to Gay Howells (Enschede, the Netherlands) for greatly improving the English.

[2] The Levinas Reader, Sean Hand (Ed.; Basil Blackwell, Cambridge, USA, 1989)

Further, "Ethos' is a system of actual value estimation. As such, it should be distinguished from 'practical morality', i.e. acting (or not acting) in line with the norms of 'ethos'.

Finally, 'ethics' is the formulation of actual 'ethos' in terms of judgments. 'Ethics' is the theory, the rational formulation and justification of 'ethos'. The main problem is to distinguish the real 'ethos' from the wrong one, to discover the correct ranking of values…"

In his further elaboration Scheler comes to the 'value person', a dynamic unity of acts and values. "This unity is only possible through the bond of love". Here 'love' receives a Judeo-Christian content, since he does not interpret it as 'eros' but as 'agape'. Love should show itself as the bowing down and descending of the noble to the ignoble, the healthy to the sick, the good and the holy to the bad and the profane." At the profane level of technical conduct this may appear in the development and design of professional products. Unlike consumer products, there is a division here between buyers and users. All too often, the latter are not consulted in any way, which may be detrimental in practice.

> An example of this is the ticket machine in Dutch railroad stations. Eleven virtual 'pushbuttons' in the touch screen are arranged in a strictly logical sequence, consisting of five choices: single or round-trip; first or second class; full or reduced price; for today or without date; paying by cash, credit card, or bank pass. It is in general not too bad for younger people, who quickly develop a motor memory for the sequence of hand movements. Older people, however, need a great deal of time over and over again, which makes them nervous and so they get into even more difficulties, especially when there are a lot of people standing in line behind them.
> It would be preferable to provide only four pushbuttons for the most common *combinations*: second class round-trip ticket, reduced price and valid for today, and the corresponding single ticket. With similar pushbuttons for the full price. The type of payment need not be chosen as the action of the user gives sufficient information. In this way, the majority of travelers would only need to touch one pushbutton instead of five. An additional pushbutton could provide access to the less common options.

In terms of values this example shows the conflict between 'logicism' and 'user-friendliness' (to the elderly), with the recommendation to forget the strict logic tree.

3. group values

In their professional groups, engineers uphold specific values, in addition to the more general ones they share with others. They often do not realize this, and react emotionally to attacks on these values. An example:

> Around 1960 robust computers became available for the direct digital control of production processes. They were equipped with a rather primitive, small operator console, as a replacement for the large, conventional wall panels. As this entailed a drastic change for the process operators, I proposed to my coworkers in the process control section that we should obtain the advice of an industrial psychologist. Their first reaction, and also that of our department head, was quite negative: "We know about computer technology, but psychologists are completely ignorant, so it's absurd to involve such a person in our project." After a period of becoming acquainted, however, good cooperation was achieved, which also proved to be fruitful in further projects.

This group value is, as a matter of fact, not objective, but inter-subjective. Like other group values, its importance and its contents are subject to changes, as a result of technological and societal developments.

The following sections show several of these group values, usually in relation to industrial projects in which we (my coworkers and colleagues) have participated. These projects were mostly in the process industries. Related or similar group values may exist in other technological sectors. The examples have been kept anonymous because they are, in my opinion, representative of all process industries.

4. designing versus producing

In the process industries product design is less important than the design of the production process .Many different experts contribute to the latter activity, who also in the long run formulate directives for process operation. The underlying assumption is that the designers are the real experts, so the production personnel should follow these directives to the letter. Still it is questionable whether this is realistic: in the acceptance test the process has to satisfy the design specifications. This test may take place in summer, when the cooling water has a high temperature, or at a time when the input materials are of a lower quality. Furthermore, the performance of some process steps, e.g. catalytic chemical reactions, is not precisely predictable. Consequently, margins are necessary to minimize the probability of failure of the acceptance test. After acceptance, however, it makes sense to benefit from better cooling in winter, a higher production rate with inputs of higher quality, better performance of catalysts, and other conditions with safety margins assumed in design.
Another difference between design and operation is related to the time factor. In their education, many process technologists have learned not to value this factor. Their ideal is the continuous process, in which the path from feedstocks to final products is split into a series of time-independent steps, realized in corresponding process equipment. The intermediate products flow continuously from one apparatus to the next. The aim is to fix all pertaining variables (such as pressure, temperature, mixing ratios) to constant values.

> In an oil refinery, where a distillation column separates isopentane from a mixture of pentanes, we put the pressure control out of operation and turned the cooling water valve to fully open. In this way, the pressure is always at the minimal value, which minimizes the use of steam. The saving is roughly 5-10% in energy utilization, or nearly the same percentage in increasing the throughput. This may not look like very much, but the cost/benefit ratio is very favorable, in view of the small investment: the main cost item was to convince the production personnel that such a subversive action could make sense.

The idea of keeping process variables at constant values even influences the operation of batch processes. There process equipment works like a sauce pan in the kitchen: first it is filled with ingredients, then brought to and kept at the right conditions, and finally emptied and sometimes cleaned before the next batch can be processed. Although conditions in the process equipment are changing all the time, many process technologists try to fix at least the temperature, pressure and/or other similar conditions.

> An example is membrane filtration, used among other things for the production of fresh water from sea water. The latter is firmly pressed against the membranes, so that the pressure exceeds the osmotic counter-pressure and allows fresh water to pass through the membranes. Gradually, the membranes become dirty and have to be cleaned by reversing the flow direction. Process technologists are inclined to keep the pressure constant. This, however, is inherently suboptimal, because optimization does not lead to a single optimal value, but to an optimal profile as a function of time. If a process model is available, then a mathematical algorithm can be used to find the optimal pressure profile. If not, one can approximate the optimal one by altering the rate of change of the pressure in a trial and error sequence. In this way, the yield of the process can be improved by several percentage points, and up to much more if operator experience is taken into account, all for a relatively small investment[3].

In these examples there is a conflict between two values: 'optimal operation' and 'constantism'. The last one comes down to an irrational rejection of time dependence.

5. ranks in processes

Process technologists, in line with engineers in general, have more affinity with new, advanced processes than with traditional ones.

[3] See: Anton J.B. Van Boxtel, Strategies for Optimal Control of Membrane Fouling (Ph.D. Thesis, University of Twente, 1991)

We[4] experienced the consequences of this attitude in a very large industrial project which had the goal of doubling the size of an oil refinery by building another 20 plants. We were consulted for advice on the organizational and human factors, including advice on the design of the central control room. There five operators (each in five shifts) had the task of supervising the 40 plants, each one at a large console suitable for two operators (in case of severe process upsets).

The topic at hand was the allocation of the 40 plants to the 5 consoles. We had proposed that attention be paid to the hundreds of connections between these plants. These could be represented in a diagram as arrows between circles for the 40 plants. It then made sense to allocate plants with many mutual interactions to the same console, so that they could be handled by the same operator. Plants with few interactions could better be put in different consoles, where human communication was required. Evidently, the allocation could now be solved as an optimization problem, in which also the operator work load had to be evenly distributed between the consoles.

The result of the optimization was that one console had a fair amount of interaction with the other four, while these four showed only a few interactions. This immediately led to a plan for the control room: the first console in the center, with the other four in a semicircle in front of it. Everybody agreed to this result, until it was shown which plants were associated with the consoles: the central console had the utilities (steam, cooling water, fuel gas, waste gas, etc.), and the others the new hi-tech plants combined with the older ones. The process technologists in the design team flatly refused to agree: “What? Those stupid utilities in the center, and our new advanced conversion plants on the periphery?” This conflict of values could only be resolved by moving a small hi-tech plant to the utilities console, so that its status was increased without too much harm to the optimization.

Here the value ‘rationality’ was saved, with a small concession to the value ‘process status’

6. status of personnel

In spite of our democratic form of government, in which every human is supposed to be of equal level, there are sometimes detrimental status differences in the status of personnel.

One example of this was the experience of my daughter in one of her first jobs, in which she was a receptionist in a business center. Behind her work place was a thick wall which separated her from the secretarial department. As a result she had little to do during the quiet hours, but she was pressed for time around 9 o’clock in the morning. In fact, the wall confirmed the difference in status between secretaries and receptionists, to the detriment of efficiency and hospitality.

An extreme example was the control room of a district heating system, where two categories of operator were required: one for the boiler section and one for the electrical section. The latter category did not wish to work in the same room as ‘those dirty boiler folks’, so a wall was erected in the control room. Still, as good cooperation was essential, a large window was fitted in the wall to enable them to see each other. Of course, actual cooperation could only be carried out by telephone.

What should an interior designer do if he/she is approached with this kind of interior architecture? Here it is quite ironic that modern democratic principles are not given a chance, even when they could improve the quality of the business.

7. work organization

Other forms of irrationality can be found in the organization on the shop floor. According to Frederick W. Taylor’s ‘Scientific Management’, there should be a strict separation between thinking and doing. Doers may not think; they merely have to do exacty what the thinkers require. This value has long been known as ‘Taylorism’.

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[4] ‘We’ stands for Dick Lenior, Ruud Pikaar, Bas Remein (Ergos Engineering & Ergonomics, Enschede, the Netherlands) and John Rijnsdorp.

An extension to management levels was described by C. Northcote Parkinson. In his view, the growth of bureaucracy can be explained by the need of older managers to delegate part of their job to more vital, younger people. Not just one person, who might be tempted to replace his/her boss. A clever manager therefore takes care to have two assistants, each for one half of the total job. I call this value ‘Parkinsonism’, in analogy with ‘Taylorism’.

Both values were realized in the control room of a new blast-furnace complex, where two shift supervisors each worked behind a personal console with several layers of computer screens, shielding them from the remainder of the control room. In front of each of these two consoles there were two smaller ones, intended for assistant shift supervisors. Finally, in front of these was a long wall panel, with meters, alarm lights, etc., for the common operators.

If one imagined the floor being rotated by 90 degrees, the result would be an organization chart exactly in accord with Parkinson and Taylor!

The question is now if this scheme is relevant to the tasks performed in the control room. The most critical one is reacting to and managing upsets in the production process. This requires teamwork between supervisors and operators, who have joint access to all the information and controls, in communication with the outside operators working in the plant. Wall panels are very suitable for this task, if provided with video-telephones and *large*, flat display screens. Smaller, individual screens, as implemented in the consoles for the shift and assistant shift supervisors, are in the wrong place and cannot be used simultaneously by several people.

This problem was clearly illustrated during a visit to a petrochemical plant, where all the supervisors and operators had been provided with a personal computer, with access to all the process data and means to control the production process. There was still a conventional wall panel, but our host said: “This has been superseded by the PC’s, so it will be removed.” Then the video screen, which was pointed at the flare, suddenly showed huge flames and a lot of smoke; evidently something was wrong. At that very moment, the shift supervisor and the operators left their PC’s and rushed to the wall panel, to tackle the problem and make the plant safe, followed by a search for the cause of the upset.

The most important and most critical task in control rooms is to handle process upsets. This requires the *collective* use of information, and good communication with operators in the plant. For this purpose wall panels have advantages over PC’s, provided they are equipped with large screens suitable for joint use by several people. .

These two examples show that ‘Parkinsonism’ and ‘Taylorism’ values are no match for the value ‘team work’.

8. knowing the process state

In the control of production processes the process state is of primary importance, particularly for a high degree of automation, where operators ask themselves again and again: “Is my process OK?”

A long time ago I was sitting next to a control room operator, in front of the (conventional) wall panel. While we were talking, he suddenly said: “ You may think I am not paying attention to my process, but from time to time I look past you to my panel to check if everything is still OK.” Indeed I had noticed that he moved his head from time to time, but had not realized that he was checking his many dozens of meters in just a few seconds.

In another control room, the conventional wall panel had been replaced by one computer screen. The operator was fanatically checking popup menu’s. In answer to our question: “Why are you so busy?” he said: “I have to know if my process is OK, don’t I?”, and continued his activity without even looking up.

So there is a great difference between offering information in parallel or in series!

In many batch processes the process state can only be judged if one goes outside to look at the actual conditions in the process equipment. The information in the control room is not sufficient for this purpose.

One of our students was analyzing the production process of a batch plant in the food sector. There, for the first time in the company, a process computer system had been put into operation. The budget was insufficient to purchase more than one screen, so that was allocated to the shift

supervisor, who also had to coordinate the work of three operators. His screen, however, was not sufficient for checking the process state. As a result, the operators frequently came into the control room to ask the supervisor to provide the values of pressures, temperatures and other process conditions, and also to open or close a valve, and so on. An ironic consequence: the shift supervisor was more of a central slave of his operators than he was their boss.
The solution was straightforward: reduce the operating personnel to three autonomous operators, who perform all the tasks as a team. Offer them jointly a wall panel, or a computer system with three screens.
Finally, the choice between a wall panel and computer screens was influenced by a personal requirement: the control engineers were afraid to lose face if they did not go for a digital solution. It might even interfere with their careers. Evidently, 'peer acceptance' overruled the quality of process control.

'Digitalism' also affects consumer products:

Most digital camera's have pushbuttons for setting the zoom, but at least one manufacturer has opted for a rotary knob: "thinking that the amateur photographer would appreciate a few old-fashioned rotary knobs side along all that digital ingenuity". It goes without saying that a rotary knob allows rapid and precise adjustment of the field of view, unlike the common pushbuttons.

9. screens at home and in the factory

At the beginning of the seventies color screens appeared in our living rooms, first rather small ones, but later superseded by screens of a larger size. At the end of the seventies, operators expected similar screens in the factory; according to the value 'homism',

The control room in the oil refinery (already discussed in Section 4) was intended to provide good opportunities for mutual contact between the operators. Large computer screens, however, formed an obstruction, particularly for short people. For this reason we proposed small screens. This was not appreciated by the automation engineers and the operators who participated in the design process. The management was not happy either because a modern control room is the showplace for visitors, who would retain a negative impression of out-of-date equipment in an advanced environment.
Then we demonstrated that it was the viewing angle that was important, not the screen size. A small screen that is close by is equivalent to a large one far away. Moreover, large screens require deeper consoles, which increases the size of the control room and interferes with close cooperation between operators. Finally, everybody agreed that small screens were the best solution.

The tricks of screen pictures can play havoc with the users

In an exhibition of automation systems, I was asked to give my opinion about a control computer with fantastic screen pictures. The whole plant was represented in pseudo 3D, in vivid colors. A virtual sun even caused glare on virtual cylindrical vessels. Future visitors would be highly impressed by such beauty. Operators, however, have no need for all this ingenuity, because they know their plant very well. Brilliant colors should therefore only be used for warnings (yellow) and alarms (red), while the plant equipment should be presented very schematically in soft colors. Even then, continuous viewing of screens was a tiring task, so they preferred not to watch TV at home.

10. towards professional value ethics

Evidently, in engineers' decision-making a variety of group values play a role. Often these are detrimental to the positive value 'rationality', which here boils down to 'optimal operation' of production processes. 'Team work' is also a positive value, with respect to both the quality of work and job satisfaction. This shows the interdependence of values, within the context of possible decisions.
Is there a system in this multitude of values? Perhaps they can be combined into a few principal professional values, in relation to engineers (at all levels) and their environment. The latter encompasses the development of modern technology, where 'new' is superior to

'old'. This principal value could be called 'newism'. It covers the following group values (already discussed):
- 'digitalism', going for 'digital' and thus ignoring 'analog';
- 'homism', introducing all the advances in consumer products into professional systems;
- 'process status', ranking production processes only according to innovation and originality.

Further, engineers view their task as controlling everything as much as possible, not only things, but also relations between people. This principal professional group value could be called 'controlism'. It sometimes leads to outdated forms of organization, in contrast to 'newism' which has already been discussed. The following professional group values fit under this heading:
- 'logicism' translating decision trees one-to-one into sequences of pushbuttons;
- 'constantism' reducing dynamics to statics;
- 'Taylorism', separating thinking and doing;
- 'Parkinsonism' maintaining a strict hierarchy which impedes 'team work';
- 'personnel status' sentencing people to subtle forms of slavery and outcasting..

Finally, there are values which parallel other group values in other professions:
- 'technocism', giving one profession (in our case engineering) the monopoly of decision making;
- 'peer acceptance' recommending respect for the present technical fashion, even if this leads to inferior results.

Of course, this system is not complete, even for industrial production. Experience in other engineering fields is without doubt desirable. In any case, it illustrates the strong influence of emotional factors in engineering practice.