Go to the Engineer

by S. M. W. Toole

'Go to the engineer and consider his words and learn wisdom.'
(adapted proverb)

At one time to call any one an automaton was by no means a compliment; today the term may be used to praise exemplary behaviour. What has brought about this change of meaning?

If we take the question on the practical side, the answer seems to lie in an analysis of the achievements of modern engineering. Today engineers can make, and do make, machines which control themselves and each other. Such machines recognize the requirements of a given situation and adapt their behaviour to those requirements by selecting the means most fitting to the end. In process of such adaptation, they apply rules which they have previously learnt and some machines can even find a new rule to meet a fresh situation and 'remember' the rule when the need occurs.

In all this machines resemble men in their behaviour and, although they have not man's variety of response, they outstrip him in accuracy and speed. They are largely self-directing and the need for supervision is reduced to a minimum. Once his machines are set up, the engineer's job is reduced to the task of keeping them in first-class condition and when necessary, 'telling' them what they are expected to do.

If we translate the behaviour of machines into human terms, we shall find what is ideally the goal of those in control of men and of those who are controlled. In many departments of life few, if any, major problems would arise if those in control could confine themselves to giving a clear definition of the programme involved and then leave things to be carried out by the various parts of the organization concerned, each man and each group working towards the achievement of a common end.

With the general objective set before them, the workers could 'get on with their own job', which is precisely what good craftsmen always wish to do. Meanwhile the management would be free to give undivided attention to the provision of satisfactory working conditions and everything else that may be included under the term 'welfare'. Paradoxically enough, top-level control is most efficent when it reduces its control to a minimum and leaves the greatest freedom for self-direction and self-control.

https://doi.org/10.1111/j.1741-2005.1965.tb05117.x Published online by Cambridge University Press

Before proceeding further we may advert to the fact that many people today are haunted and hampered by a fear of automation. Their fear is not without foundation since automation, like all good things, can be and is abused; but why let it be abused? Whether we welcome it or not, automation has come to stay and, if we do not want it put to a wrong use, we must concern ourselves about its right use. In the office, in the home, in the factory, on the farm and even in the seats of learning, from primary school to university, automation has a right use, a good use. In whatever walk of life we are, in whatever field of science we are interested, few of us can truly say that automation is not our affair, that it should be left to the engineer. It is precisely from the engineer that we all have much to learn. Even though our own work involves no engineering, it is worth while studying the principles that the engineer has evolved for the control of his machines and for extending the range of their self-control.

Any intelligent person who takes purposeful action of any sort is soon aware of the need for some check on his activity to make sure that it is really achieving its purpose. This is where the engineer makes use of 'feedback' in his system of controls. This 'feedback' plays an important part in the practical application of the science of cybernetics in any system involving control and communication. It makes it possible to test the responsive behaviour of men as well as of machines and although its application in organizations of men is limited in comparison with its use in assessing the performance of machines, nevertheless there is much that those who handle men can take over from the engineer.

Whatever the programme chosen to achieve a given result, we cannot be sure that the result has been achieved unless there is a feedback showing the extent of any deviation from the result intended. Finding that deviation is taking the measure of any corrective action necessary. If we wish the system to be self-controlled, the deviation should operate a mechanism which will correct the error and rectify future action. In other words, the machine will have 'learnt by experience' and in future will compensate for the deviation by appropriate action.

In order to achieve such control in a system, its circuit must be closed; otherwise there will be wasted activity and loss of information through the open end. To ensure such a closed circuit it must necessarily contain certain elements: Prediction, Information, Measurement, Coding and Communication, Response and Co-ordination. If these six elements are set out as six steps towards the realization of a perfectly controlled system, it will be evident that the devices of the engineer can be handed over to the managers of men and be of help in devising techniques in the field of human relations.

1. PREDICTION At every stage the engineer (or the manager) must be able to predict what effect the action ought to have in order to achieve the desired result.

2. INFORMATION The engineer (or the manager) must be informed as to the actual effect of the action.

3. MEASUREMENT Before taking the next step, he should be able to measure the deviation between what is and what ought to be at the moment.

4. CODING & COMMUNICATION Some convenient form must be found for coding the measured difference between what is and what ought to be. This coded deviation must be transmitted to the centre or centres apt for receiving such communication and taking appropriate action.

5. RESPONSE There must be prompt response to the signal received from the communicating centre. This response should be action which will compensate for the deviation. Where there is a choice of response a selecting mechanism will also be required.

6. CO-ORDINATION There must be co-ordination among the parts when the response is complex. To provide such co-ordination further feedback circuits may be necessary between the different parts of the responding machine.

It will be seen from the above that the problems confronting the engineer at work on controlled systems really do resemble the problems of the man controlling men. Both of them must devise indices which will measure and record any deviation from the appointed path; both must strive to provide compensating action, often at many levels, to rectify the deviation; both must secure co-ordination among the various parts so that the compensating action may not defeat itself. In the managerial system, however, there are peculiar difficulties arising from the human element in the system and the resulting number of variables, all operating at the same time. Men cannot be treated like machines, unless they cease to be men. Nevertheless, the engineer can still lead the manager a long way.

The engineer has long since realized that the technician cannot deal with too many indices at once; there are limits to the number of dials that one man can watch. This difficulty has been met by picking out the key indices, making use of analogues and shunting some of the work onto other machines. The same initiative is called for in the management of men, but because the field of operation is wider and the difficulties more complex, the control and direction of men is not so easily systematized.

It is when the fifth step, response, is reached that the manager of men meets with more complications than the engineer. The deviation from the purposed result has been coded and signalled, but there is a defective response. This is because all men do not, and sometimes cannot, respond to the same set of facts in the same way. In many cases, if there is to be any response to a signal on a certain level, the signal will have to be re-coded in a form intelligible to those receiving it. Men at working level and

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men at headquarters do not necessarily express themselves in the same terms.

Choice of appropriate action brings further difficulties when the agents are men and this is where the analogy between mechanical systems and human systems seems to break down. Eliciting a response from a man necessitates a different kind of approach from that of the engineer whose task is to elicit a similar response from a machine. The engineer is dealing with a mechanism, with a strictly limited range of answers, e.g., the thermostat has only a two-way response – it increases or decreases the draught. The man, or group of men, in control of some activity in which men are involved has usually many answers from which a choice must be made. When the choice lies between action and inaction the answer to the problem may be very complicated indeed. All the same, the process by which men arrive at decision is in principle like that by which self-controlling machines decide which course to choose and pursue.

Another critical choice is connected with decisions of timing – the course of action decided upon may lead to failure if it is implemented too early or too late. It follows thet men with rigid minds are ill-fitted for direction and control – they are lacking in power of decision and they have not the mixture of firmness and flexibility that makes choice prompt and sure.

Unfortunately, it is precisely with rigidity and obstinate adhesion to the enforcement of a time-honoured set of regulations that the word 'control' is associated in so many minds. In this respect the present-day interest in cybernetics may do much to build up (or should we say, build in?) better standards of conduct in our relations as controllers or as controlled. We are led to grasp the cybernetic fact that control is mutual and that, to be effective, it involves a two-way relationship. We do at last begin to see the need for 'feedback' in the chain of command, but we do not always accept the full implication of what we see. An exaggerated idea of the difference between giving an order and passing down a piece of information may become a kind of beaver-dam obstructing the lines of communication and control.

The word 'Cybernetics' was coined by Norbert Wiener, a man who was deeply concerned with the impact of science on our society. In finding a Greek root, he did not make his choice at random. The word *Χυβερνητης* means 'steersman'. That derivation is worth pondering upon. Control does not mean the exercise of power by one over another – it is steersmanship. One of the clearest indications of imperfect control is the frequent need for the exercise of power. In a good organization power rarely intervenes. Ideally, control is not achieved by power but by the flow of information secured by informative feedback. This communication should not be in one direction only and the direction it takes – up, down or sideways – is determined by revelance and not by source. Responsibility is built into particular places in the structure of an organization, but control is mutual.

This concept of organizational control is not new; at least a glimpse of it has long since been caught by those who wish to see human beings put to human use and not bent under the domination of machines. Nevertheless its impact on the managerial mind is still too slight and it fails to find a really practical expression.

Speaking of feedback as a means of securing good control leads to consideration of possible defects in the organization of the feedback. Here again we may turn to the engineer for help. The problems he has had to deal with in systems of mechanical control are similar to the problems arising in human organizations. Both kinds of control system are subject to oscillation arising from defective feedback. This is not the place for minute details. In brief, the trouble may be caused by a feedback that is either too sensitive and results in correction that is too hasty and too violent, or one that is so sluggish that correction comes too late. In such cases the parallel between the mechanical control system and the human control system is easily seen.

There is an even more useful conclusion to be drawn when the defect in feedback is due to its not being sufficiently selective. When this is the case there may be transmission of disturbances to parts of the organization with no equipment for dealing with them. The attempt to provide a good system of communications can result in needless upsets. Multiplication of feedback circuits is not always a good thing.

Before we part company with the engineer, there is another idea we may take over from him. In the process of devising his control systems, the engineer has shown us clearly that control is everywhere and he has revealed the principles that govern the interaction of systems within systems. He has shown us how the component parts of his machines are held together in such a way that a change in one variable brings about a compensating change in others and thus maintains the stability of the whole.

Once we have grasped the fact that there are laws which govern the interaction of systems, whether the systems be human or otherwise, we are on the right path towards a better understanding of humanity as we find it in ourselves and in others. The theory of control, taken over from the scientist, has transformed the world of engineering in an amazingly short time. It also offers to both men controlling and those controlled a gateway that leads to hitherto undreamed of developments in every kind of social organization that is capable of holding together and acting as a whole.

At first sight the study of communications and controls may seem a formidable task to tackle, especially for the 'not-so-young' whose school and college days lie far behind them. Nevertheless, if we make up our minds not to be hidebound and obstinate in our adherence to old ways of thought; if we open our hearts and our minds to new influences and readily embrace a new range of disciplines, we shall find the effort a rewarding one. It takes courage to look at facts in the cold, north light of the truth but, given that courage, we shall see that the difficulties are not insuperable and that the chief obstacle to better ways and better days for all men is ethical and that it lies within ourselves.

The scientist and the engineer have gone ahead and can already show us the fruits of their discipline and toil. If their labour is to come to full fruition, it is now up to the rest of us to profit by their findings and to develop their great work in a wider human sphere.

Notes on Contributors

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https://doi.org/10.1111/j.1741-2005.1965.tb05117.x Published online by Cambridge University Press