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# Towards a new technology policy*

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## Historical Background

South Africa's industrial history began with the discovery of gold and diamonds during the last century, and the mining industry was the first chief component of our technological development. During the past six decades, quantum leaps were made in other fields, too, when other industries and research bodies such as Escom, NDC, Iscor, Sasol, Foskor, Alusaf, Mintek, C S I R, S A B S, and A E C were established. These meaningful additions have two outstanding characteristics. Firstly, they were linked mainly to primary activities such as energy and minerals and, secondly, their establishment was to a large extent due to the driving force of individuals such as Van der Bijl, Van Eck, Rossouw, Schonland, and Roux, rather than to impersonal government policy. Encouraging signs of the evolution of such policy has emerged during the past few years.

About ten years ago, a former minister, Fanie Botha, appointed an *ad hoc* committee to examine the minerals policy, and in the report I put forward a proposal regarding the need for greater beneficiation of the country's minerals. Today, because of enthusiastic zeal on the part of Mintek's leadership, the beneficiation of minerals has become a well-known concept in the RSA.

In 1985, in a White Paper on a Strategy for Industrial Development, the government accepted in principle the decisive role of technology and innovation in the successful implementation of industrial development and export. At the beginning of 1987, the Cabinet accepted a proposal from the Scientific Advisory Council that dealt with the relation between science policy and technological development.

The most important step in this evolution process took place when President P.W. Botha formally embodied technology in a ministerial portfolio. The creation of a Ministry of Economic Affairs and Technology is a real milestone in the industrial history of this country. At the same time, an outstanding choice was made in awarding this ministry to Mr D.W. Steyn, an engineer by training and profession, who immediately started laying and building up the necessary constitutional foundations.

In March 1987, the Advisory Council for Technology (ACT) was created, consisting originally only of representatives of the State and semi-State bodies. A year ago it changed drastically to become a smaller body of about 10 members the majority of whom were industrial leaders in the private sector.

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Forming a directorate on technology promotion in the Department of Trade and Industry was the next step in the development of the Department. Its work is to act as the backbone in the formulation and development of a policy for technology by the ACT and to implement the related functions.

The contributions of this section, as well as the inputs of ACT members, gradually gave form to what I am going to discuss here. This will soon be presented to the minister in a formal document with the idea of having a technology policy approved by the government. Because of the nature of such a policy, it cannot be rigid but must continually be adapted and extended, and thus remain valid.

You will note that so far I have discussed technology development mainly from the point of view of the State. Apart from mining, a considerable manufacturing industry has come into being in the RSA during the past few decades, which makes up 22 per cent of our GDP and 20 per cent of our exports. Although meaningful, it cannot be compared with that of countries such as the UK, West Germany, and Japan, where manufactured goods respectively compose 66, 75, and 89 per cent of export earnings.

## Introductory Concepts

Technology is closely linked to man's efforts to control his environment for his own benefit. This has led to the building up of a body of expertise behind every piece of equipment for extending natural abilities.

Until about two centuries ago, this was brought about mainly as a result of trial and error but, by the end of the eighteenth century, technology had increasingly become the result of the planned application of scientific knowledge. It goes without saying that this relationship demands that a policy for technology and science should be inextricably linked. In fact, during the past few decades, science in the broadest sense has begun to play a more significant part. This can be seen in sociopolitical factors such as environmental action.

In a given community, technology can either be imported or generated locally. It can entail incremental improvements or take place by way of quantum leaps. In the twentieth century, the level of technology has become the parameter by which a community is classified. Terms such as *First World* and *Third World*, *developed* and *developing country*, today refer to the level of technological development experienced by the community in question. Other spiritual and cultural values, unfortunately, play a relatively small part in such value judgements, and indicate once more the extent to which technology influences modern man's attitude to life and his world view.

### Technology's Contribution to Prosperity

Because of the recovery of Europe and Japan after the Second World War, it has become generally accepted that manufactured products, rather than natural resources, constitute the determining factor in international competition. Japan's production of manufactured goods, for instance, increased by a factor of 4 between 1965 and 1982, while its consumption of minerals and metals remained more or less constant during that period. The indicators for South Africa are clear. Although we benefit enormously from the exportation of our minerals, we cannot stop there since we shall cease to be a relevant factor in world economy, with an attendant deterioration of the prosperity for all our people.

Technology in the form of products and process technology is the key to the successful and competitive production of manufactured goods. This is true of individual firms, as well as of the country as a whole. Improved technology means higher productivity per labour unit with a concomitant decrease in inflation, increase in international competitiveness, and an increased contribution to exports.

Long-term economic growth takes place because of increased capital investment and labour coupled to improvements in technology. Solow[1], who received the Nobel Prize for economics in 1986 for his pioneering work in this field, demonstrated, as far back as 1957, that the economic growth in the USA from 1909 to 1949 entailed an average annual growth in GNP of 2,9 per cent. This growth embraced the following components: an increase in capital was responsible for 0,32 (11 per cent), an increase in labour was responsible for 1,09 (38 per cent), and improvements in technology contributed the remaining 1,49 (57 per cent).

According to Gee[2] (1989), the contribution of technology upgrading to a growth in productivity has been estimated to be as high as 40 to 70 per cent. In contrast, capital growth contributes 15 per cent to an increase in productivity, while only 12 per cent can be attributed to improved education and training of the labour force on the production line. These figures will differ as a matter of course from one community to another, but the general tendency is revealing.

### Technology Grading

The lowest and highest levels of technology in any community are usually linked in a continuous spectrum. For the sake of discussion, we will take a look at four discrete levels[3] (Moravcsik, 1983).

*Level 1* is that of a subsistence economy, noted for its use of primitive agriculture and home industry. The technology is traditional and empirically developed, and is not based on scientific research.

*Level 2* is low-level technology, still not associated with own research and development but taken from elsewhere. Economically, it is fairly competitive because the attendant wage structures are low.

*Level 3* is another step upwards from Level 2. The technology has been imported chiefly, and a degree of association with local research and development has taken place. Import replacement is the first consideration, although the exportation of sophisticated goods also occurs. Competitiveness has its base in relatively cheap energy, raw materials, and labour.

*Level 4* represents leading-edge technology as found in developed communities. This needs highly skilled manpower, and renewal is constantly in demand in order to remain competitive.

The schooling of the South African population spans such a wide spectrum that Levels 1, 2, and 3 can all be seen here with a few isolated instances of Level 4. As a matter of interest, Levels 1 and 2 are characterized by factories as opposed to industries. Strictly speaking, the RSA does not really have an automobile industry, but rather automobile factories. In contrast, Detroit has an automobile industry. However, this country can truly claim to have a synthetic-fuel industry and a mining industry. Research, development, and manufacture, right up to the end product, take place locally. This, in my opinion, describes a real industry.

Table I shows the relative contribution to research and development in the private sector by the State in several countries. It can be accepted as a general tendency that, the higher the level of technology rises, the greater is the contribution by the private sector. The challenge is to progress through each level to the higher one so that the welfare of each member of the community can benefit materially and socially.

TABLE I
RELATIVE CONTRIBUTION TO THE FINANCING OF R&D BY THE PUBLIC SECTOR (PS) AND PRIVATE SECTOR* (PRS) IN SOME SELECTED DEVELOPED AND DEVELOPING COUNTRIES

| Developed countries, % | | | | Developing countries†, % | | | |
|---|---|---|---|---|---|---|---|
| Country | Year | PS | PRS | Country | Year | PS | PRS |
| Japan | 1984 | 20 | 80 | S. Korea | 1982 | 41 | 59 |
| UK | 1981 | 26 | 74 | Rep. of China | 1986 | 60 | 40 |
| USA | 1984 | 29 | 71 | RSA* | 1985 | 72 | 28 |
| W Ger. | 1983 | 40 | 60 | Centr. Afr. | | | |
| France | 1984 | 46 | 54 | Rep. | 1984 | 74 | 26 |
| The Nether- | | | | Brazil | 1982 | 77 | 23 |
| lands | 1982 | 48 | 52 | India | 1982 | 86 | 14 |
| Average | | 35 | 65 | | | 68 | 32 |

* By 'private sector' is meant that part of the business sector from which State bodies are *excluded*.

† In the case of these countries, defence research (wholly or partially) is *included*. In the case of the other countries, it is *excluded*.

### Innovation

In any production process, improvements take place in the course of time but vary in extent. For the sake of convenience, technological innovation is divided into two categories: incremental and quantum innovation. Among examples of the latter are the use of transistors in electronics, glass fibre in communications, and carbon-in-pulp in gold extraction.

It is surprising to note what the impact of these two types of innovation has been on the economy. During this century, England has probably made the greatest number of breakthroughs in science and technology (if the size of the population is taken into account), and Japan the least. In contrast, Japan is at the top of the list as far as incremental improvements are concerned, and it is hardly necessary to point out which country's economy has developed the faster.

Normally, it can be expected that the private sector plays the largest part in incremental innovation. When the inevitable profit motive is taken into account, incremental improvements demand smaller capital inputs and there is an easily calculated chance of success. In contrast, quantum innovation demands large capital inputs coupled to higher risks but, if it succeeds, the success factor is usually high and the term of serviceability extended. Therefore, decision-making for quantum innovation has to take place relatively high up in the company hierarchy and, in a country such as South Africa, where the number of organizations rich in capital are relatively few in number, it is often the responsibility of the State to take the initiative, for instance in establishing large corporations.

**Dominant Role of South African Raw Materials**

It is inevitable that, in discussions of the future of South African technology, specific reference be made to the mining industry.

The part played by this magnificent industry need not be repeated here. Its contribution to the GDP, foreign-exchange earnings, provision of jobs, multiplying factor in related activities, potential as a lever in international politics, and so forth, are well known. However, this great material blessing has also brought about some disadvantages. There is an unhealthy dependence in the RSA on the price of gold as a metal. It has created an industrial culture that is so strong and established that it cannot easily be changed. The inertia of the mining industry with regard to the beneficiation of minerals is to some extent understandable. The most obvious of these reasons are as follows.

(a) It is difficult to compete by means of a refined product with overseas clients who buy the primary product. One or two of the clients may be drawn into such a project, but all of them cannot be involved. In addition, the intense competition of other mineral-producing countries who enter the market daily should always be taken into account; in other words, mining companies should concentrate on keeping their own technology in the forefront.
(b) The initial legislation and incentive mechanisms were related to the primary industries.
(c) The associated marketing network, because of its colonial past, sets the prices of raw materials to local processors.
(d) There is no logical argument that is not in favour of other financial bodies, apart from the mining companies, participating in the erection of more-advanced processing plants.
(e) There has been a certain lack of entrepreneurial spirit, which was, indeed, characteristic of our earlier mining history.

It is a matter of concern that the contribution by manufactured goods to foreign-exchange earnings during the past decade has decreased in relation to that of raw materials. The implication is that the country has become less defensible economically.

The entire situation can be illustrated by the absence of several industries including jewellery production, the manufacture of platinum-group metal products, the production of titanium oxide and vanadium metal, the large-scale production of stainless steel, and the large-scale production of chromium chemicals.

**Participation by the Authorities in Technological Development**

It is a world-wide phenomenon that authorities take the initiative to stimulate new technologies. The motive varies, for instance, from international image and prestige (the USA's space programme); through defence (the USA's Star Wars programme); to the provision of economic flexibility (France's programme in the field of robotics).

In South Africa, a number of such programmes have come into being as mentioned in the historical overview.

A technology policy should steer chiefly towards the participation of the authorities, whether directly or not, to promote technology. In the RSA, such a policy should take the following factors into account:

- new forefronts such as
  - informatics (computers, micro-electronics, opto-electronics)
  - computer-aided manufacture (design, control, robotics, sensors)
  - materials technology (metal alloys, light alloys, plastics, ceramics, superconductors, magnetic materials)
  - biotechnology;
- outstanding local needs such as
  - urbanization and housing
  - education and training needs
  - provision of water
  - physical infrastructure
  - security services and strategies;
- this country's rich mineral resources and relatively cheap energy, which provide powerful indicators for technology development;
- marketing, raising the question of what sort of products demonstrate strong market growth trends;
- the manpower problem, in which the optimum development and utilization of trained manpower remain the greatest single issue in the RSA regarding technological progress;
- criteria for the evaluation of technology projects.

In regard to manpower, I seriously doubt whether, if the price of oil increases greatly in the immediate future and and oil boycott becomes more effective, we would be able to start up another synthetic fuel plant within the next five years, even if the capital and the best technology in the world were available. The reason for my doubt is the lack of adequate highly trained manpower.

It is worth pausing for a moment to examine future expectations for trained manpower in various fields of technology. Figs. 1 and 2 are self-explanatory.

Figs. 1 and 2 show the birth rate and the number of pupils who leave school with matriculation exemption.

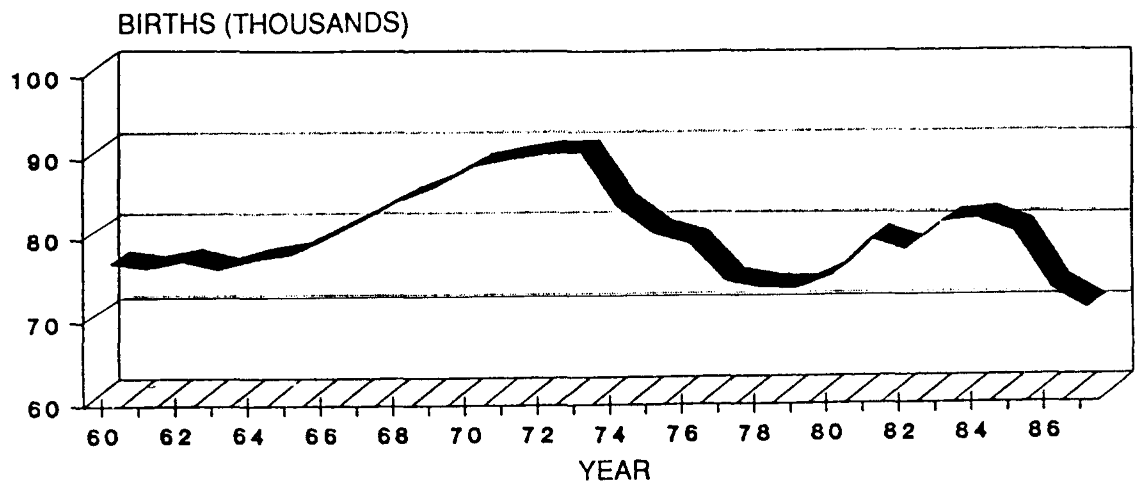


**Fig. 1—Birth statistics of Whites from 1960 to 1987 (Scientometric Advisory Centre)**

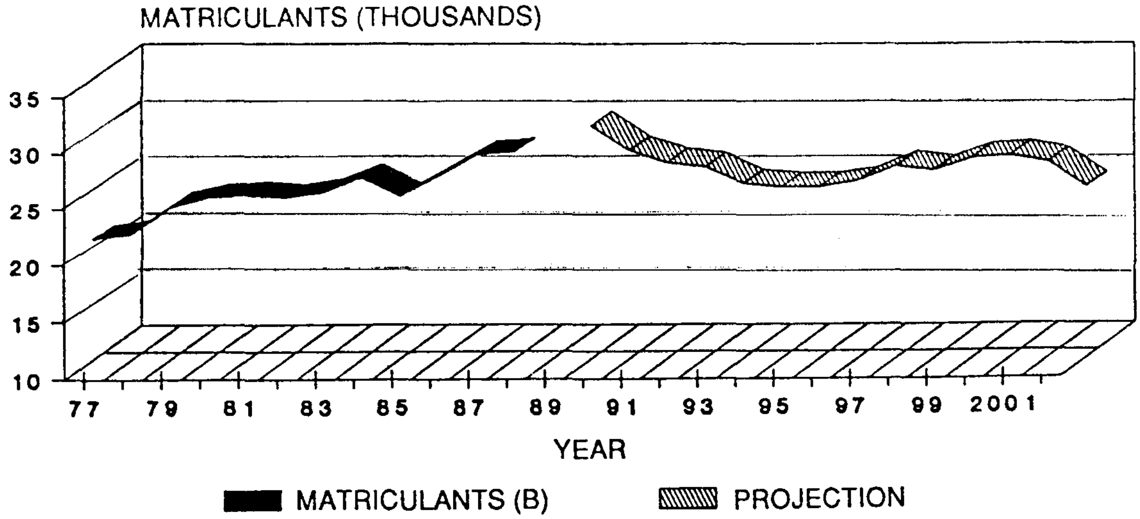


**Fig. 2—White pupils who matriculated from 1970 to 1987 (Scientometric Advisory Centre)**

It appears that, out of every 100 births, 33 pupils achieve matriculation exemption after 17 or 18 years. This is a relatively stable relationship over time.

The same percentage of pupils leave school without matriculation exemption, and the rest drop out before standard 10. Furthermore, only a certain percentage of students with matriculation exemption (61 per cent) get a university degree. This is a fair percentage. In the USA, for instance, 60 per cent of the matriculants receive degrees. To sum up, demographic factors determine the extent of the high-level manpower among Whites: out of every 100 born, 33 achieve matriculation exemption, 20 a degree, and 2,7 a degree in the natural sciences and engineering.

From Fig. 1 it is apparent that the birth rate has dropped considerably since the early 1970s. The number of births decreased from almost 90 000 in 1974 to a mere 70 000 in 1987—a decrease of 22 per cent. This decrease will result in a proportional drop in the number of students at all levels and, eventually, in high-level manpower. We can expect a drop of 22 per cent in the need for educational services in the White community, and a proportional drop in the ability to meet high-level manpower needs by the year 2000.

Considering the fact that the Coloured, Indian, and Black populations contribute about 19,0 per cent (B degrees) and 13,2 per cent (of all degrees) to the numbers of science and engineering graduates, and that there could hardly be double that number in the following decade, the warning signals are ominous.

The total South African population (including the TBVC countries) will grow from about 39 to 51 million over the next decade. Simply stated, there will be 30,7 per cent more people to feed and clothe, coupled to a drop of more than 20 per cent in engineers and scientists to carry the technological growth.

Possible solutions are obvious.

(a) A greater percentage of White pupils should be drawn towards these fields. The educational system will play a key role in this respect.
(b) A greater percentage of people of other colours should become involved.
(c) Trained people from overseas should be drawn in greater numbers.
(d) Technology development and choices should take the available manpower into consideration.

The strength of a chain is determined by its weakest link and, as far as the technology chain of the RSA is concerned, high-level manpower is the weak link!

In regard to the criteria for the evaluation of technology projects, it should be noted that the RSA will not be able to tackle all possible projects because of the natural limitations on its resources. A mechanism should therefore be developed by which final priorities can be determined for projects and logical responsible choices can be made. Such a mechanism should weigh up not only projects of a technological nature against one another, but all projects including those of a social nature.

For this purpose a weighing matrix should be drawn up. Table II may serve as an example.

A great number of elements are incorporated in the weighing matrix. The immediately obvious question is: What units are being used to quantify the elements? The answer is rands and cents. For instance,

- the 'money' value of an engineer can be calculated;
- ecological damage can be calculated if the costs of repair are multiplied by a chosen coefficient;
- loss in foreign currency involved in the buying of equipment can be calculated in terms of commercial and the financial rands;
- strategic value can be calculated in terms of the stockpiling value of the product if it is not obtainable elsewhere.

The above illustration is, of course, an over-simplification of a complex calculation. Sensitivity analyses of selected parameters would be necessary, although it should be remembered that absolute evaluations are not in question, but the relative values of different projects.

Large State-supported projects have shown success to a greater or lesser extent but, as mentioned above, most of them came into being through the drive of a specific personality. It would be a most instructive exercise to apply this weighing-matrix technique in retrospect to projects that were tackled in the past, and then to compare their theoretical merits with what actually occurred after their commissioning.

### State Action in the Promotion of Technology

State participation in the promotion of technology can be divided into the following categories.

(1) *Technological Infrastructure*

The State created a technological infrastructure, including institutions such as the scientific councils (CSIR, Mintek, MRC, HSRC, and SABS), universities, technikons, technology parks, and State corporations such as IDC, SBDC, AEC, and Technifin.

The whole tendency of closer contact with the private sector by these bodies can be seen as an outstanding factor for success in the RSA. At the same time, they form a pool of expertise to advise the government in many ways such as on the evaluation of weighing matrices for decision-making.

(2) *State Purchases*

Purchases by various government bodies represent a large percentage of the demand for goods on the market. If made judiciously, such purchases can provide a base for new products and contribute greatly towards technological development. The effectiveness of this policy instrument depends on the extent to which the buying power can be concentrated. With regard to certain products, some government bodies already achieve much because of their buying power.

An example of this type of action is the deliberate policy of the South African Posts and Telecommunications to increase the local content of equipment. This was a decisive factor in the establishment of an

TABLE II
WEIGHING MATRIX

| Elements of importance | Maximum State investment | | | |
|---|---|---|---|---|
| | 0–R5m | R5m–R20m | R20m–R100m | >R100m |
| State income/expenditure account (subsidies, taxation, excise, etc.) | >R5m | R5m–0 | 0–R5m | <R5m |
| Job creation | Extensive | Great | To some extent | Very little |
| Upgrading of the relevant technology pool | Great | A great deal | Negligible | Omitable |
| Strategic importance | Great | To some extent | A little | None |
| Ecological effect | Healthy | Neutral | Detrimental | Severely detrimental |
| Product advantage | Lower price, better function | Lower price, same function | Higher price, better function | Higher price, same function |
| Completion | None | Little | Normal | Severe |
| Life cycle | Unlimited | 25 years | Fairly long | Limited |
| Availability of raw materials | Freely | Readily | Scarce locally | Scarce, few suppliers |
| Availability of technology | Plentiful | Readily | Scarce, licences required | Scarce |
| High-level manpower demands | >10% of worker corps | 10–5% | 5–1% | <1% |

electronics industry. The Standing Committee for Electronics is trying to co-ordinate the purchase of electrical equipment by various government bodies.

(3) *Quantum Innovation*

Since the initiative for incremental innovation actually belongs to industry itself, the responsibility for initiating quantum innovation belongs to a great extent to the State.

In the past, the State undertook macroprojects of this type in the RSA often for strategic reasons, but usually as a result of the drive of certain industrial leaders. As already indicated, such actions ought to be judged in a more quantifiable way—not merely on a re-active basis but more pro-actively. In fields where the State in any case carries the responsibility for aspects such as education, projects can be launched more easily. An example of this is the development of hardware and software for electronically supported mass education. An imaginative programme of this kind can make an enormous contribution to education, greatly stimulate the electronics industry, and increase exports to developing countries.

(4) *Overall Integration of State Policy*

Technology development, manpower needs, and the promotion of productivity and, economic incentives are all linked, but these activities fall under different State departments and overall integration is an absolute necessity for optimum industrial growth.

The following is an illustration of the need for such integration: in the 1950s Japan was relatively strong in labour-intensive industries such as the textile industry; although the President of the Bank of Japan held the opinion that, because of existing international specialization, Japan should not start its own automobile industry, the Ministry of International Trade and Industry (MITI) endeavoured to create an all-embracing industrial structure that would be able to accommodate capital-intensive industries; the Japanese automobile industry was born out of this approach.

This demands that global industrial policy should take technology development fully into account; in fact, it should be permeated with sensitivity to technology.

(5) *Creation of a Suitable Economic Climate*

Government action in the economic field is characterized by some reliance on market forces and profit motives, while initiative rests with the private sector. The State plays a part in creating the climate and of facilitating and, at most, of activating events.

Aspects such as the following are referred to:

- possible incentives or support for technology and product development
- the use of research bodies by firms
- a taxation system conducive to technological innovation
- a supportive tariff structure
- effective protection of intellectual property
- effective export incentives
- deregulation and privatization
- competition
- availability of venture capital
- effective infrastructure
- an effective regional development policy
- a clear economic strategy for the future
- a favourable political climate, which is indispensable for successful technological and industrial development, and at present the RSA lacks this to a great extent.

(6) *Creation of a Suitable Social Climate*

The South African society should move away from the syndrome that this is a country of sunshine and racial problems.

The technology consciousness of a country is reflected, among others, in the choices of its youth when they enter tertiary institutions for further training. If we take a look at the number of graduates in chemical and metallurgical engineering in a few countries, we find that Japan and the USA (per capita) produce six times as many as South Africa, while the UK has produced four times as many and Australia twice as many during the past decade.

The need for a strong indigenous technical manpower corps is essential for stable technological development in the long term.

One of the great stumbling blocks in technological progress is the resistance to change by the worker corps. In the 1960s, the British ship-building industry lost the race to Japan because the worker corps did not want to replace the technique of welding with that of riveting. An enthusiasm for technological innovation should be inculculated in society.

Politicians react to public opinion and, if the public is made aware of technology, State decision-makers will react accordingly.

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