The Need for Technology Policy Programs: Example of Big Data

Richard de Neufville

Abstract The modern mature state is necessarily responsible for designing and managing complex systems. These frequently involve both technological and political issues simultaneously. The modern state therefore requires cadres of professionals cognizant and skilled in technology and policy. Yet many countries, in particular those that have recently transitioned to the state of being modern states, traditionally educate their prospective leaders exclusively in either technical or social expertise. The conclusion is that modern mature states need educational research programs that prepare cadres for leadership in Technology Policy. An example makes the point. As suggested by the case of Singapore, coherent policy formation for "big data", for the collection and use of massive data on individuals and collective enterprises, requires leadership that is both sensitive to the political issues, and knowledgeable about the technological potential.

1 Overall Argument

This presentation argues that modern mature states need to establish and nurture programs in Technology and Policy. The role of these programs would be to prepare future leaders for intelligent, thoughtful, and effective formation and implementation of policies in the wide range of societal issues that necessarily involve advanced technologies in some fashion.

This paper develops this conclusion through logical analysis using syllogisms. A syllogism is the process of proceeding from a major premise A, through a minor premise B, to a conclusion C. For example:

- Major premise: "All human beings are mortal."

R. de Neufville (✉)
Institute for Data, Systems, and Society, Massachusetts Institute of Technology,
77 Massachusetts Avenue, Cambridge, MA 02139, USA
e-mail: ardent@mit.edu

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- Minor premise: "Politicians are human beings."
- Conclusion: "Politicians are mortal."

The strength of such arguments of course depends on the validity of each premise. To make a convincing argument it is thus necessary to establish the credibility of the premises. For example, the conclusion that "Politicians are mortal" rests upon the strength of the claims that "All human beings are mortal" and that "Politicians are human beings."

This presentation uses two syllogisms to make its argument. The first makes the case for the need for leadership cadres who can integrate technological and policy considerations. The second syllogism combines this preceding conclusion with the observation that current educational processes generally do not prepare the requisite cadres, to arrive at the conclusion that mature societies need to fill this gap and create situationally appropriate forms of educational and research programs in Technology Policy.

The paper illustrates the overall argument using the case of "big data." This is the term many observers now commonly use to describe:

> "… the large volume of data – both structured and unstructured – that inundates a business on a day-to-day basis. But it's not the amount of data that's important. It's what organizations do with the data that matters. Big data can be analyzed for insights that lead to better decisions and strategic business moves."
> http://www.sas.com/en_us/insights/big-data/what-is-big-data.html?gclid=CNXtLS6k8kCFRUOjgod4KQMgA#dmhistory

While many thinkers have discussed the issues associated with the torrents of information that now flow into databases, common lore attributes the creation, or at least the popularization, of the "big data" term to industry analyst Douglas Laney.

2 Need for Leadership that Integrates Technology and Policy

The syllogism to develop this part of the argument is:

- Major premise: "States oversee complex technical/social systems.'
- Minor premise: "Proper oversight of these systems benefits from proficiency in technology policy."
- Conclusion: "States benefit from having proficiency in technology policy."

2.1 States Oversee Complex Technical/Social Systems

Mature states necessarily oversee the design and management of complex systems. Their societies expect that they will be able to switch on lights, obtain potable water

from a tap, communicate electronically with their friends, manage human services and so on. They expect their governments to make sure that there is the proper organizational structure to fulfill these expectations.

The emphasis here is on overseeing the functioning of these complex systems to serve societal expectations, in contrast to providing for these needs directly. Indeed, mature governments have evolved a wide range of organizational structures to provide expected services to the public. These cover a broad range, for example as regards the provision of water services:

- Direct provision of services through some governmental agency such as the Singapore Public Utilities Board that supplies water nationally;
- Self-sufficient special purpose independent public agencies, such as the East Bay Municipal Utility District (EBMUD) that supplies a range of cities in the San Francisco Area;
- Concession agreements for a limited period, as for the Metropolitan Waterworks and Sewerage System of Greater Manila; and
- Private companies that the government regulates, as through the Water Services Regulation Authority (Ofwat) in England and Wales.

The point is that in every case the government has, as it must, some degree of control over the provision of these complex systems, either directly or indirectly through appointments of the managers, contractual obligations, or regulatory processes.

Typically, the management of the complex systems falls within the domain of either technical professionals or leaders with some formation in the social sciences. For example, engineers typically plan and design the systems that provide water services, electric power, or communication networks. Complementarily, lawyers, politicians, and social scientists generally manage the range of social services the public expects of the state. It is thus easy to think that in the modern state the management of complex systems is split between two cultures: that of science and technology on the one hand, and that of the liberal professions on the other [1].

However, although we might characterize the management of each of these complex systems as either ‘technical’ or ‘social policy’, each inevitably combines elements of the other. For example, much of the rationale for the provision of potable water is a matter of social policy concerned with public health and the fear that high rates would encourage the use of contaminated supplies. Conversely, the effective delivery of social services depends strongly on the use of technological means to identify members of the public requiring these services, and to deliver the intended support to them.

The conclusion is that the modern state does oversee complex systems that jointly, to some degree, combine a mixture of technological and social dimensions and concerns. This validates the major premise.

2.2 *Oversight Benefits from Proficiency in Technology Policy*

Experience demonstrates that the design and management of complex systems frequently benefit from a joint proficiency and understanding of both technology and policy. Example after example shows that lack of understanding of both aspects can lead to difficulties, a waste of time and money, and a generally inefficient, ineffective management of complex systems.

Cases in point that are perhaps most accessible publically concern the way technical managers have been blind to social realities and political processes. The history of the development of the Interstate highway system in the United States is a general example. Engineers in state highway planning agencies used technical models to specify the routes and width of the highways. This approach worked reasonably well for planning motorways through the open countryside, but largely failed in urban areas. The highway planning mindset at that time, in the 1960s, simply did not grasp either the reality that urban populations had different priorities than the traffic engineers, or the need for a negotiated political resolution of conflicting perspectives. They did not know how to deal with citizen groups that were interested in maintaining neighborhoods, in preventing the division of their cityscapes into islands separated by 4 or 6-lane highways. Moreover, the highway agencies demonstrated little understanding of political processes. This lack of appreciation for social and political realities led to extended battles that led to notable costly, time-wasting defeats for highway departments in Boston, San Francisco, and many other cities. They had neither understanding nor skills in developing or implementing effective Technology Policy.

The lack of understanding of the "other", of policy processes by technologists or of technology by liberal professionals, is not confined to the scientific or technical communities. For example, the economists who designed the original privatization of electric power in England set up a system they thought would provide fair competition and keep prices competitive. Unfortunately, they apparently did not understand the way power networks work. In a nutshell, they were ignorant of Kirchhoff's Laws. The result was that they inadvertently created market rules that allowed the major providers of electricity to game the system and essentially extract monopoly prices from consumers. They thus cost the British consumers an enormous amount. Eventually, the British Government revised the market for electric power through a new regulatory system, following which prices reportedly dropped by 40 %—which is a measure of the cost to the public of managing the power system without a good understanding of its technological realities [2].

These two examples document the potential cost of trying to design and manage complex systems with the proper understanding of both the technological and political economic aspects of the situation. This validates the minor premise.

2.3 States Benefit from Proficient Technology Policy

From the preceding we can conclude that modern mature states can benefit from leadership that is knowledgeable in and understanding of both the technological and political economic aspects of the complex issues that they oversee.

The emphasis here must be on the potential benefits. That is, that states can benefit significantly from cadres of leaders who have developed an integrated understanding of both the technological and political economic aspects of an issue. This is not to say that every senior engineer should also be politically savvy, or that every economist or politician should have a significant understanding of the technology that underpins the system of interest. It asserts that they are a number of significant situations in which an understanding of technology and policy may be vital.

3 Need for Technology Policy Education/Research Programs

The syllogism to develop this part of the argument is:

- Major premise: "States benefit from having proficiency in technology policy."
- Minor premise: "Technology Policy programs are generally unavailable."
- Conclusion: "States need to develop Technology Policy programs."

The previous section has already made the case for the major premise.

3.1 Technology Policy Programs Are Generally Unavailable

There are only a few Technology Policy programs that prepare cadres for leadership. Salient programs are:

- Technology Policy Programme at the University of Cambridge (UK)
- Engineering and Public Policy at Carnegie-Mellon University (USA)
- Technology, Policy, and Management at the Technical University of Delft (the Netherlands)
- Science and Technology Policy at George Mason University (USA)
- International Science and Technology Policy at George Washington University (USA)
- Science, Technology, and Public Policy at Harvard University (USA)
- Science, Technology, Engineering, and Public Policy at University College London (UK)

- Technology Policy Program at the Massachusetts Institute of Technology (MIT) (USA)
- Science, Technology, and Environmental Policy at Princeton University (USA)
- Science, Technology, and Public Policy at the Rochester Institute of Technology (USA)
- Science and Technology Policy at Stanford University (USA)
- Institute of Science, Technology, and Policy, Technical University of Zürich (ETHz) (Switzerland)

This is a suggestive list of the major Technology Policy programs worldwide.

We should also note that these programs differ substantially in their focus and concerns. Some are institutionally located in the Schools of Engineering, some in Schools of Management, and others in Schools of Public Policy. Correspondingly, the emphasis of their programs and research activities are quite different. Furthermore some have around 40 years experience (Carnegie-Mellon and MIT), and others are just beginning (University College London and ETHz). In general it is fair to say that there is no standard model for technology policy programs [3].

Most of these educational/research programs are in the United States. Four of these are in Europe, and one of these (ETHz) only started up in 2015. Beyond this, Technology Policy programs hardly exist. This account demonstrates the lack of such programs in general.

It is pertinent to ask at this point: why are Technology Policy programs prevalent in the United States but not elsewhere? It is difficult to answer this question conclusively. But the following explanation is at least suggestive. The fact is that technical education in the United States differs significantly from the patterns that are common elsewhere in the world. Thus the criteria for accrediting engineering programs in the United States includes the requirement for

> "… a general education component that complements the technical content of the curriculum and is consistent with the program and institution objectives." [4]

In practice this means that engineering students in the US take a quarter of their credits—that is one full year out of the usual four in North America—studying liberal arts subjects. Notably, this is the case at MIT. The graduates of American engineering and technological programs have received at least a rudimentary grounding in the subjects needed to prepare them for developing leadership in effective design and management of complex systems. The result is that American engineering students are primed to develop a range of skills that integrate technical and political economic concerns.

This approach to technical education contrasts with the traditional practice outside of North America, that holds that engineering students study technical matters almost exclusively. That pattern largely prevails in Europe, in educational systems derived from European traditions, and in many Asian contexts. For example, the Dutch university system has traditionally divided its faculties into quite separate groups: Alpha (for languages and the arts); Beta (for technical subjects); and Gamma (for the social sciences). Putting this bluntly, many educational systems make a point of

keeping technological and political economic education quite distinct and separate. This means that the technically oriented professionals from those educational cultures are quite unprepared for dealing with issues of social or economic policy in any post-graduate curriculum and research program. This situation makes it difficult to develop programs that combine Technology and Policy.

In any case, we may observe that the existing situation validates the minor premise that "Technology Policy programs are generally unavailable".

3.2 States Need to Develop Technology Policy Programs

The conclusion from the logical argument presented is that modern, mature states owe it to themselves—in the interest of designing and managing their complex systems—to develop academic programs of education and research in Technology Policy. In many fields they will benefit from having such a program. The states will benefit from having a cadre of professionals who are competent technically, understanding of the social and political economic realities, and skillful in meshing these competencies in the management of the complex systems they deal with.

The practical question is then: how might it be possible to develop the desirable Technology Policy programs? It is not enough to have a good idea, it is essential to know "how to move the furniture around", to have some effective ways to implement ideas. In particular, it is necessary to have the needed intellectual, professional, and financial resources.

Appropriate human capital is a necessary condition for success in developing Technology Policy programs. It will not be possible to develop effective Technology Programs without persons prepared for the field, with relevant experience, and interested in applying their capabilities. Without these ingredients, we can do nothing.

But the availability of human capital is not sufficient. Some kind of catalyst is indispensible to bring the human capital together for the creation a new kind of educational and research program. The development of Technology Policy programs has an interesting history in this regard. Historically, individual entrepreneurial pioneers founded and developed most of the existing programs. For example, Prof. Granger Morgan created and led the Carnegie-Mellon program for some four decades. Similarly, Prof. Henk Sol led the creation of the Delft program. Almost all the existing Technology Policy programs stem from some kind of individual entrepreneurial desire to create such activities. To date, most Technology Policy programs originated through a 'bottoms-up" process of institutionalization. Only a few programs, such as the recently initiated ETHz program in Switzerland, appear to have come from a "top-down" process, as an expression of high-level institutional strategy. By the way, this observation offers another explanation for the prevalence of Technology Policy programs in the United States; its culture generally values and promotes individual entrepreneurship, in academia in particular.

Modern states cannot rely on chance and uncertain individual initiatives to initiate and develop the capabilities they require. To obtain the resources and capabilities they need, they should plan and adopt a suitable strategy of initiation, encouragement, and implementation. The first phase of a successful strategy is likely to build upon some one or more themes that are nationally salient as policy issues. This approach can ride the wave of existing interest, and of the funding in this concern.

Financial resources are of course also necessary to establish Technology Policy programs. However, the sums required are not extraordinary if the basic human capital exists within the existing university context. Existing programs have largely developed by building on existing faculty and facilities already on staff. Mostly they have needed the organizational and individual commitment to reassign positions around new themes in Technology and Policy. Start-up money is primary needed to create initial momentum and stimulate excitement.

Since this conference on Complex Systems Design and Management is being held in Singapore, let us take a moment to think about out Singapore could set up an exciting program in Technology and Policy:

- Let us first observe that Singapore already has a set of faculty who have prepared in world-class programs in this field—several of them are participating in this conference.
- Second, Singapore also has a range of senior faculty with significant experience in policy at the highest levels.
- Third, it has at least two well-established institutions relevant to the area:
  - The Lee Kuan Yew (LKY) School of Public Policy that already serves as the regional hub in its field, attracting future leaders from across Asia and beyond; and
  - The Institute for Engineering Leadership in the faculty of Engineering at the National University of Singapore.
- Fourth, both the LKY School of Public Policy and the Institute for Engineering Leadership have close associations with a number of foreign professors and experts who have been working in technology policy for decades.

In short, Singapore has the central necessary ingredients for providing regional leadership in technology policy.

Given that Singapore has a strong base, both in terms of human capital and institutionally, how might it proceed to establish a Technology Policy endeavor? How might the Government develop and provide the capabilities it will need in this area? How might it proceed to mount suitable educational curricula? What should it do to mount a meaningful research program that could productively inform the nation? How might it develop the ideas and concrete plans for managing and developing Technology Policy to serve the nation and the region?

As a suggestion I propose that Singapore could build upon its current commitment to create a “Smart Nation”. At its core, this is a project to build national connectivity, to create an operational system to collect and comprehend data, and

thus to provide the basis for devising and providing enhanced services [5]. As such, it represents an extensive investment in a technologically complex system, one that will surely last many years. This project also raises, indeed brings with it, a broad range of important policy issues, for example:

- How will the nation deal with the consequences of "big data", the availability of immense of amounts of detailed data on so many aspects of our lives? We have already seen many of the ways "big data" has been disrupting established institutional arrangements.
- How should the nation adjust its urban development (if at all) to take advantage of the capability of big data? The Lee Kwan Yew Centre for Innovative Cities has already initiated discussions on this [6].
- What policies should the government establish to protect itself, the public, and commercial enterprises from inappropriate, abusive intrusions into privacy?

It seems clear that the Smart Nation project not only provides a platform for thoughtful developments in Technology Policy, but also indeed calls for research and education in what we might call "big data Technology Policy".

4 The Case of "Big Data"

We now turn to the case of "big data" in some detail. The purpose is to illustrate the need for Technology Policy programs through a specific example. The discussion first gives a brief portrait of the nature of "big data", and generally suggests the aspirational goals people have for this field. The argument next describes, with specific reference to Singapore, how the governments and others are currently managing the development of "big data". This points out a range of apparent gaps that reinforce the need "big data Technology Policy".

4.1 Nature of "Big Data"

The development, exploitation, and use of "big data" offer a range of really exciting and challenging opportunities. To many of us, comparisons of the possible impact of "big data" to the effect of the "Industrial Revolution" of two centuries ago seem reasonable. In this regard, the kind of definition of "big data" cited earlier widely understates the prospects. Indeed, that definition focuses on the quantity of data:

> "… the large volume of data – both structured and unstructured – that inundates a business on a day-to-day basis. But it's not the amount of data that's important. It's what organizations do with the data that matters. Big data can be analyzed for insights that lead to better decisions and strategic business moves."
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> http://www.sas.com/en_us/insights/big-data/what-is-big-data.html?gclid=CNXtLS6k8kCFRUOjgod4KQMgA#dmhistory

Many of us believe that 'big data" will, eventually, fundamentally change the nature of our society. Its ramifications have already changed our patterns of living and being just since the turn of the century. Think about the social media and how small local incidents (a terrorist act, a police confrontation) can spread worldwide and mobilize political forces rapidly. Recognize how new enterprises based on "big data" (such as Uber and Airbnb) have already disrupted established industries and overturned pre-existing regulations and conventions. Consider the potential to pinpoint minute hidden relations between seemingly disparate factors (such as connections between individual mutations on genetic codes and forms of cancer), and thus to establish specific treatments and cures.

In the event, the following discussion builds upon the concept of "big data" that includes both the wide range of supporting technologies (such as sensors, communication systems, and mathematical analyses) *and* the application to an array of societal issues. With the creation of the MIT Institute for Data, Systems, and Society (MIT IDSS) in 2015, MIT explicitly subscribes to this perspective. As the research program of the MIT IDSS states:

> "Advances in technologies, including big data, sensors, and communications networks, combined with increased computational capabilities and the ability to process and analyze vast amounts of data, have created the opportunity to holistically, systematically, and scientifically address complex systems that touch upon every aspect of our modern lives." http://idss.mit.edu/research/

4.2 Management and Development of "Big Data"

The technological effort to create the basis for "big data" has been, and will continue to be enormous. What we have accomplished to date is miraculous: just consider what a smartphone can do for us—compared to what was at the forefront of technology in the year 2000. This accomplishment has required enormous achievements in the design and use of physical materials (computer chips, fiber optics, etc.) and in mathematics (network analysis and control, compression of data, etc.). These kinds of technical achievements have and are driving the development of "big data".

It is thus normal that technologists and technical institutions have a commanding role in the development of "big data" projects. Thus in Singapore, the Infocomm Development Authority leads the way in the "Smart Nation" project. It is instructive to look at how they present their task.

Infocomm's view of their task for the development of "big data" in Singapore appears in Fig. 1. It projects the image that the project is all about the technology. The first phase is the creation of an underlying communications network, followed by picking up available data and storing and sharing it in some way. Indeed, their label for the work is the development of the "Smart Nation Platform".

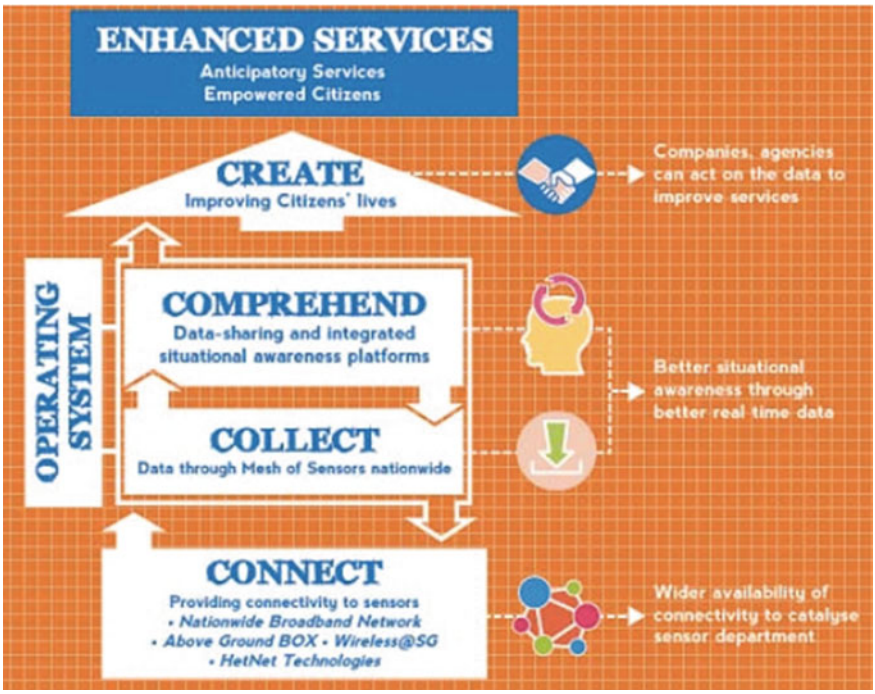

Fig. 1 Overview of Smart Nation Platform for Singapore. https://www.ida.gov.sg/～/media/Files/About%20Us/Newsroom/Media%20Releases/2014/0617_smartnation/AnnexA_sn.pdf

Although Fig. 1 identifies the aspirational goals for the Smart Nation Platform as "improving citizens' lives" and "empowering citizens", notice that the immediate task is not confronting the major policy issues involved. Consider the matter of privacy, for example. How is Singapore as a nation going to protect its citizens from unwanted and undesirable intrusion into their intimate details? We can imagine the operational efficiencies that might derive from translating paper medical records into digital formats. In counterpart however, this process facilitates easy access to issues most citizens properly would not want to be publically accessible—such as whether they ever suffered from depression, had a sexually transmitted disease, or underwent an abortion. Unless the state establishes careful policies and practices concerning the privacy of digital personal records, the era of "big data" might be considerably worsen rather than improve the lives of many citizens. In the United States, for example, extended public debates and regulations about health information (US HHS) have taken place. In general, the development of "big data" inherently entails issues of privacy: we do not mind giving various bits of information when we expect it to be lost in a mass of unsearchable data, but we may feel quite differently when we know that governments or companies may access and exploit it. For instance, whereas I now do not mind the obligation to provide my passport or resident ID number when I book a ticket for a theater in Singapore, I

well might not want to share the details of my peculiar private viewing pleasures. Thus the Smart Nation project requires careful development of social policies.

We must also recognize that "big data" makes available all kinds of information that was previously unthinkable. The traditional transaction records accessible to governments (land transactions, tax declarations, military and criminal records, etc.) are quite limited compared to what is now possible. Already, the use of smart phones enables the telecom providers—and anyone with whom they wish or must share the data—to track our individual locations minute by minute. Moreover, we can expect the deployment of all kinds of other sensors. Consider the Singapore National Science Experiment (https://www.nse.sg/) that is deploying thousands of wearable sensors (developed in association with the Singapore University of Technology and Design, https://www.nse.sg/sensg/about-sensg/). These enable the researchers to track ambient conditions (temperature, humidity) and activity (sitting or walking) of school children throughout their day. No doubt that this information might help the Land Transport Authority plan its transport services. But which parent wants to broadcast the details of how their child walks home at night? Similarly, while closed circuit TV (CCTV) can be useful in deterring crime or identifying the perpetrators, what should our social policy be concerning its use, in an era when technology will be technically able to tag our faces digitally and our track our activities in real time via CCTV streams?

These social issues are not in evidence on Infocomm's agenda for the Smart Nation Platform. This is proper insofar as their competence and remit centers on technology. The recognition of this reality is simply a statement of fact that identifies the gap between what now exists and the need for Technology Policy programs that somehow jointly address both the technological and the political economic issues associated with the concept of the Smart Nation, and with "big data" generally.

4.3 Need to Develop Technology Policy Programs for "Big Data"

The preceding account stresses the gap between what currently appears to dominate the development of "big data", in Singapore in particular, and what is desirable from the perspective of the state. In a nutshell, the need is for some kind of integrated, joint examination of the technological and the political economic policies that associated with a Smart Nation. Some of this discussion has begun in Singapore [11]. This is a good start. Singapore needs to do more, at a higher level.

Recognizing this kind of need, my colleagues at the MIT Institute for Data, Systems, and Society have made their own commitment in this regard. Specifically, they state their mission in the following terms:

> "[Our] research will incorporate both the technological aspects of the application as well as the critical human and institutional aspects inherent in most societal challenges." …
>
> "IDSS seeks to integrate these areas — fostering new collaborations, introducing new paradigms and abstractions, and utilizing the power of data to address societal challenges." …
>
> "Our ability to understand data and develop models across complex, interconnected systems is at the core of our ability to uncover new insights and solutions." http://idss.mit.edu/research/

5 Conclusion

The conclusion is that modern mature states need educational programs that prepare cadres for leadership in Technology Policy. Such programs exist at leading universities. These demonstrate what it is possible to achieve. Modern mature states should adopt a coherent strategy to develop such institutions.

Singapore already has the necessary assets, in terms of human capital and institutions, for the development of an effective Technology Policy program. As it is generally most effective to start such programs around salient important issues, the suggestion is that Singapore should use its Smart Nation project as a basis for catalysing its own efforts in Technology Policy.

Such an effort should be valuable to the nation. Coherent policy formation for "big data", for the collection and use of massive data on individuals and collective enterprises, requires leadership that is both sensitive to the political issues, and knowledgeable about the technological potential.

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