ABSTRACT

The nexus between regulation enforcement and engineering failures
by Athol Yates

The deaths caused by the recent Turkish earthquake, the Canberra hospital implosion and the Esso Longford gas plant explosion all have one thing in common. Good building codes and safety procedures existed but they were not followed nor enforced.

Over the last 2 decades, the trends of de-regulation and self-conformance have effected most engineering activities. These trends have the potential to reduce costs, increase innovation and benefit the nation. But they also may lead to a decline in design quality, a failure to apply relevant codes and an increase in safety risks for the community.

The maintenance of engineering standards is a critical factor in ensuring that the reforms actually benefit society in the long-term. This presentation examines the evidence of the development and enforcement of engineering regulation, and finds that there is much to be concerned about.

The nexus between regulation enforcement and engineering failures

12,000 people died in last year's earthquake in Turkey. New buildings toppled over, others concertined. Turkey has a sound building code which was lasted updated in 1997. Its code includes ductile detailing requirements, such as 135-degree hooks in column hoops and cross ties, denser transverse reinforcing in the vicinity of beam- column joints, and strong-column-weak-beam design concepts. So how can the building failures be explained?

20,000 died in the recent earthquake in India. About 183,000 houses were completely flattened and 420,000 suffered severe damage. A very large number of engineered structures, such as reinforced concrete and precise concrete buildings, also suffered catastrophic collapse. India uses IS1893, IS4326 and other codes for seismic design and construction of buildings. So how can the building failures be explained?[1]

In 1997, the Canberra hospital demolition went tragically wrong. One person was killed when she was hit by debris among a watching crowd of 30,000. The planned implosion was governed by Demolition Code of Practice and OH&S legislation. So how can this tragedy be explained?

In 1998, the Esso Longford gas plant in Victoria blew up killing 2 workers. Just 6 months prior to the explosion, Esso's health and safety management system was audited by a team from Esso's owner, Exxon. The system, called Operational Integrity Management System, is internationally renown. So how can this tragedy be explained?

[1] See attachment by Kevin McCue on the Australian lessons which can be drawn from the earthquake.

A common element to all these tragedies is a failure to enforce the existing regulations.

In the case of the Turkish earthquake, according to James L. Witt, director of the US Federal Emergency Management Agency (FEMA) “The problem in Turkey appears to have been lax enforcement, especially during the latest building boom around Istanbul. Buildings that collapsed are showing rampant signs of code violations. Many new ones were built with inadequate-strength concrete and reinforcements. In some older buildings, additional stories were apparently added on without the necessary permits or engineering”.[2]

In the case of the Indian earthquake, according to an international expert review, there was a “lack of enforcement of code provisions in some government organisation, and the large-scale violation of code provisions in the private sector”.[3]

“The design codes [in India] are only technical guidelines and their compliance is not mandatory since enactment of building codes is a state subject. In most states, compliance with the IS codes is required for government structures, while very few urban areas have adopted compliance with IS codes for private constructions. Even when compliance with IS codes is mandatory, the enforcement of the code specification is often found lacking and the codes are violated with impunity. The process is further complicated since, as per the relevant building bye laws, the structural engineers do not assume any legal responsibility of their designs.”

In the case of the Canberra hospital implosion, the coroner found that ACT WorkCover did not follow established safety processes. It failed to ensure that the explosive workplan required by the Demolition Code of Practice was met. It also failed to scrutinise departures from the original demolition workplans and to issues appropriate prohibition notices in accordance with the OH&S Act to ensure the methodology was safe not only to the workplace employees but also to the public at large.[4]

In the case of the Esso Longford explosion, the Royal Commission found that Esso failed to protect its workers by not delivering on the self-regulatory requirement of the OH&S Act and not implementing corporate policy of undertaking a hazard and operability study (HAZOP). HAZOPs have been common practice in the process industry since the mid 1980s. The Royal Commission stated that "Esso recognised the particular significance of a HAZOP study for Gas Plant 1 (GP1), given the age of the plant, the modifications made to its initial design and the changes to design standards since the plant was built. These reasons grew stronger with the passage of time. Indeed, a HAZOP study for GP1 was planned to take place in 1995 and the cost of such a study was included by Esso in

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[2] http://www.state.ct.us/dps/DFEBS/UPDATE/updnov99.pdf
[3] The Bhuj Earthquake of January 26, 2001 *Consequences and Future Challenges* http://www.civil.iitb.ac.in/BhujEarthquake/Chapter.04.pdf
[4] ACT Coroner, 1999B, *Executive Summary of the Inquest findings, comments and recommendations into the Death of Katie Bender on Sunday, 13th July 1997 on the demolition of the Royal Canberra Hospital Acton Peninsula, ACT, pp.* 273-274.

successive budgets during the years 1995 to 1998".[5] The Royal Commission identified that the failure to undertake this process was a contributing factor to the disaster. "The failure to conduct a HAZOP study or to carry out any other adequate procedure for the identification of hazards in GP1 contributed to the occurrence of the explosion and fire."[6]

These examples are not unique. They are just the most public examples of regulatory enforcement failures. Any regulation system can suffer the same fate. Any can degenerate from effective to ineffectual without enforcement.

Systems are not enough to ensure compliance. This was one of the most useful thing to come out of the review of the ACT Government response to the Coroner's Report into the Canberra Hospital implosion. According to the reviewer, Tom Sherman, "WorkCover now has good procedures in place for monitoring the use of explosives in the ACT. Blasting Plans have to be submitted and those plans are vetted by an independent expert. Post-blast reports are also required. I am reasonably confident that the procedures, skills and culture now in place in WorkCover provide good prospects for effective regulation of the use of explosives".[7] However he noted that changes to a system alone are not sufficient to ensure that established processes are followed. "The best legislation and contracts will be of little use if those responsible for the monitoring compliance with workplans fail to carry out their tasks."[8]

Enforcement failures are particularly common during periods of massive change. Over the last 2 decades, the engineering environment in Australia has been experienced this.

Under the mantras of slashing red tape, unshackling business and other de-regulatory euphemisms, we have seen the rise in self-regulation, self-conformance, voluntary codes of practice, performance standards and best practice guidelines.

These have the potential to reduce costs, increase innovation and benefit the nation. But they also may lead to a decline in design quality, a failure to apply relevant codes and an increase in safety risks for the community.

Much of the reform has been achieved through the Legislative Review process under National Competition Policy. This started in 1995 and aimed to review about 1,800 pieces of legislation. It states that a review should:

- clarify the objectives of the legislation;
- identify the nature of the restriction on competition;
- analyse the likely effect of the restriction on competition and on the economy generally;
- assess and balance the cost and benefits of the restriction; and

[5] Parliament of Victoria, 1999, *The Esso Longford Gas Plant Accident: Report of the Longford Royal Commission*, Victoria, p 203.
[6] Parliament: 235
[7] Sherman, T, 2000, *Report of an assessment of the ACT Government's response to the Coroner's Report on the inquest into the death of Katie Bender at the demolition of the Royal Canberra Hospital on 13 July 1997*, p. 33.
[8] Sherman, p 343.

- consider alternative means for achieving the same result including non-legislative approaches.[9]

All reviews were predicated on the assumption that any legislative restriction to competition is unnecessary unless proved otherwise. The only acceptable justifications for legislation that restricts competition is that:
- the benefits of the restriction to the community as a whole outweigh the costs (normally called the *public interest test*); and
- the objectives of the legislation can only be achieved by restricting competition.[10]

This approach reflects the neo-classical economists' view of government intervention in the economy. Neo-classical economics states, among other things, that the market provides the most efficient allocation of resources and that government intervention is only justified if three requirements are all met. They are:
- a demonstrated market failure;
- the market failure imposes a significant cost to society; and
- government intervention will actually correct the failure.

Neo-classical economic theory groups market failure into five main varieties; public goods, monopolies, negative externalities, information asymmetry and disequilibrium.

These reviews were normally undertaken by consultants with an economics background on behalf of governments. The quantification of the cost-benefit analysis can be highly complex and consequently, non-economists had difficulty contributing to the process. In addition, due to the difficulty in quantifying the public interest component of a piece of legislation (often through a lack of knowledge by the consultant), the public interest hurdle was frequently not met. Consequently de-regulation has occurred where a more multi-disciplinary analysis may have resulted in a different outcome.

As an illustration of how the evaluation of regulation needed to be framed, below is a breakdown of the costs and benefits using this taxonomy for the regulation of professional engineers. As you read it, think about the difficulties of quantifying these costs and benefits in economic and other ways.

Benefits

- **Overcoming information asymmetry:** A registration system aids the market by providing information to consumers on the education and experience levels of the people who can offer engineering services. This enables consumers to make more informed decisions. In particular it reduces the tendency for consumers to choose on price alone due to their inability to consider other factors.
- **Lower transaction costs:** A registration system lowers the transaction costs for consumers as it provides them with information on how to identify appropriate service providers. Without this, some consumers, particularly one-off consumers, will probably either abandon the search or make a less than optimal decision.

[9] Competition Principles Agreement, Clause 5 (9), 1995.
[10] Competition Principles Agreement, Clause 5 (1), 1995.

- **Reducing negative externalities:** As engineers are responsible for the integrity of buildings, structures and numerous consumer items, many people besides the consumer of the engineering services are affected by the service. A registration system provides some guarantee of reducing this externality by eliminating non-qualified engineers and preventing engineers found guilty of misconduct from continuing to practice. This externality is enhanced by requiring companies to have professional indemnity insurance.
- **Increasing positive externalities:** A registration system provides a competitive edge over other jurisdictions and countries when exporting goods and services. This is because in the international trade of engineering products, certificates of compliance from registered engineers are often required and one country may give preference to other countries with registration systems.

Costs

- **Increased cost of engineering services:** A registration system increases the cost of services to the consumer by limiting the number of potential providers by enforcing entry or experience restrictions; and forcing up costs for engineers by requiring them to hold professional indemnity insurance and paying licence fees.
- **Reduction in the choice of engineering services:** A registration system reduces the options for consumers who prefer lower quality advice and lower costs which could be provided by engineering para-professionals and non-engineers who can substitute for professional engineers.

My contention is that due to the lack of involvement by those who understand the beneficial outcomes of regulation, too many engineering functions have been de-regulated. These people, including engineers, probably didn't get involved as they either didn't know the legislation was being reviewed or felt unequipped to influence the decisions. Incidentally, the failure of engineers to engage in these debates is one of the reasons why the profession is loosing respect in the community. If you don't publicly stand up for the public interest against short-term financial interest, how does the public know engineers abide by a code of ethics and are not simply technocrats for hire? The legislative reform process offered a stage for this but engineers rarely stood on it.

So instead of a legislation-based regime, numerous non-legislative schemes were introduced. These included:

- codes of practice
- voluntary agreements
- education campaigns
- self-regulatory codes
- co-regulatory systems
- laissez faire

All of them rely, ultimately, on some form of enforcement to ensure that good outcomes are delivered. This enforcement can be grouped together under the 3 principles of deterrence, detection and prosecution.

I will discuss each in turn and comment on their applicability and limitations under rare extreme events, such as earthquakes, floods, fires, and severe impacts.

Deterrence can be achieved through several ways, notably market forces.

Market forces are fine if both buyers and sellers are informed and can weigh up the costs and benefits of different price and service offerings. However in the case of extreme events, it is unsuitable. This is because most buyers are not informed. The general person does poorly at weighing up risks. For example, they give higher weighing to more frequent, lower consequence hazards than to less frequent, higher consequence hazards. Even for organisations which you would think are informed, my observation is that they are becoming less so. This may be because there are less technical people in senior roles, such as asset buyers, than in the past. For proof, look at the IEAust 2001 survey of government agencies. We asked government engineers involved in contracts if they had sufficient technical expertise to be an informed buyer for their project. About 25% said the expertise was inadequate.

A couple of interesting issues arise if an enforcement system relies on market forces but these are not effective in regulating behaviour. Even if building owners were fully informed of the risks of earthquakes, they still would not buy the appropriate level of earthquake insurance. This is because they know that if a severe earthquake occurs, government relief will be forthcoming. Given that insurance companies also know that the government would underwrite them, they put far less effort into encouraging building owners to buy more resilient designs or upgrade existing buildings. This in turn results in diminished incentives for engineers and architects to gain the knowledge required to build better structures.

In addition, if there is no penalty for those who do not follow a voluntary code nor get benefit if they do, then not following the code can result in an unfair advantage.

The second principle of enforcement, detection, requires skilled people, sufficient resources and an appropriate detection strategy.

Detection resources have always been in short supply but over the last decade, they have been reduced even further. Government detection agencies have downsized, detection staff have moved to policy development, or on-site inspections have been replaced by paper based audits of systems.

A typical response from government when the regulatory system shift from prescriptive regulation to self-regulation is that as certain work was no longer needed, such as sending inspectors to companies to identify breaches of prescriptive rules and regulations, staff are shed. But when new functions are identified, such as sending inspectors to sites to ensure employers were providing a safe workplace and issuing prohibition or improvement notices, instead of increasing staff numbers, the tired mantra of doing more with less is trotted out.

One of the key difficulties for regulators is obtaining skilled staff. The consequences of this can be seen in the delayed introduction of safety case regimes for major hazardous facilities around Australia. Although the need for this approach was identified 15 years ago, only 2 states have introduced the enabling legislation and even then they had to import staff from the UK and US to ensure the system was monitored properly.

The final principle of enforcement is prosecution. For this to be effective, prosecutions actually have to occur and be seen to occur.

Unfortunately, in the rare event of a prosecution, most are settled out of court with non-disclosure clauses a condition of agreement. This limits the awareness of a prosecution and undermines the effectiveness of enforcement.

There is no one best solution for ensuring enforcement is effective across all engineering activities. Whatever approach is selected, it requires that the regulatory approach is appropriate in the first place, appropriate strategies for enforcement are implemented and that the system is continually reviewed. Interlocking checks and balances are essential.

Another critical element, notably for rare extreme events, is the active participation of practitioners in the regulatory environment. If practitioners believe that the system is not working, they are the ones with the greatest chance of changing it. Relying on government to see the impending disaster is to wait for godot.

Don't believe the clap-trap about regulation stifling business. Just like financial regulation and fair trading rules, sound building codes build prosperity, not endanger it. They can turn a disaster into a minor disruption.

Arguing for increased regulation is not popular. But this is the distinction between leadership and popularity - you do what needs to be done rather than what the majority of people want in the short-term. If professional engineers want to start regaining the community's respect, then they have to show strong leadership and do what is right, rather than what today's ideology rewards.

The Gujarat earthquake near Bhuj, Western India

26 January 2001
by Kevin McCue

The major earthquake that struck in the western Indian State of Gujarat (the region of Kutch) near the city of Bhuj on January 26, 2001 (Indian Republic day) resulted in the worst natural disaster in India; at latest count more than 20 000 people are known to have died and more than 200 000 made homeless. The death toll will undoubtedly rise as the recovery operation proceeds.

The earthquake At magnitude (Mw) 7.7 the earthquake was indeed a major event. The causative fault was perhaps 100 km long with a maximum throw of a few metres though no details of surface faulting have yet been reported. More importantly for structures, the ground shaking on firm foundations would have been quite strong within about 50 km of the fault. Numerous aftershocks have been and are being reported, the largest magnitude (mb) 5.8 just 2 days after the mainshock on 28 January.

The damage The graphic TV footage and photographs show massive and widespread destruction and collapse, particularly of 3 to 5 storey apartment buildings. Already Indian engineers have attributed the destruction to the total lack of resilience of homes and multi-storey dwellings due to poor mortar and workmanship, the codes not being followed and obviously no inspection/certification by competent engineering authorities.

The Hazard The earthquake hazard map of India shown on the Global Seismic Hazard Assessment Project (GSHAP) map rates this area the highest risk in peninsula India, comparable to the highest earthquake hazard in Australia which is centred on the Meckering area east of Perth Western Australia. Indian Standards for earthquake resistant construction date back to 1893 and the Standard was last revised in 1994. Most buildings designed and built to the Standard should have withstood the earthquake without collapse – the goal of the Standard.

Tectonic setting and History of Seismicity Peninsula India is considered to be a Stable Continental Region (SCR) like Australia but, like Australia, has a history of strong earthquakes. The epicentre in the Kutch (Cutch) region is some 450 km from the nearest plate boundary to the west but the historical record shows a remarkable level of activity there. Many sources such as Richter (1958) describe the effects of the 1819 Rann of Kutch earthquake (see the abstract below)

Prior to this latest Kutch earthquake, the worst of the most recent peninsula India earthquakes was that at Latur (Killari) on 30 September 1993 which killed about 10 000 people when their adobe homes collapsed in the magnitude (Ms) 6.2 earthquake (the same size as the 2 June 1979 Cadoux WA earthquake).

Records of earthquakes in the Kutch region go back to at least 1844, the most recent large earthquake occurred there in 1956 when 'there was great damage and loss of life` (Richter, 1958). In 1906 there was a magnitude (Ms) 6.2 earthquake there (Ambraseys, 2000).

Lessons for Australia If the 1819 event in the Kutch region had occurred in Central or Western Australia we would probably have no knowledge of it because of the sparse population and non existence of seismographs then. The largest known Australian earthquake occurred offshore WA in 1906, its magnitude (Ms) 7.2. There is no reason to suppose that a magnitude 7.7 earthquake could not occur in Australia and if it struck a populated area there would be great damage and collapse of structures. Few buildings in Australia have been designed or constructed to resist earthquake shaking. After the magnitude (Ms) 6.8 Meckering WA earthquake only some large buildings in Adelaide and Perth and large Commonwealth Government buildings were so built. Domestic housing was not considered in the Loading Code until after the 1989 Newcastle earthquake when Australian Standard AS1170.4 –1993 was introduced and even then compliance was required only in a few of the higher risk regions. In the main Australian buildings are neither designed nor built to resist earthquakes so they will not.

Australia and Peninsula India have similar levels of hazard, they are both SCR's or intraplate regions and whilst large earthquakes do occur they are infrequent. The consequences however of a large infrequent earthquake in an urban area are terrible as recent earthquakes in Kobe Japan, Turkey, Taiwan and now India continue to demonstrate. The earthquake near Newcastle in 1989 was a relatively small earthquake but caused widespread damage to unreinforced masonry structures, hospitals, schools, an ambulance station and fire station.

Even if a country has a modern building code, and Australia is about to introduce a new joint Loading Code with New Zealand, there is no benefit if the code can be ignored, if the regulations of the code are not applied, or the structure designed but not inspected for compliance during construction. No one in Australia has addressed the problem of pre-code buildings, those not designed for earthquakes but which are more vulnerable because they have also suffered loss of strength and resilience due to aging and differential settlement. The populace may think they are protected when in fact they are not.

In recent years some effort has been made to study the paleoseismicity (prehistoric earthquakes) of the Kutch region. Below is an abstract of a paper on the deformation characteristics in the Kutch seismic zone. A similar study should be done in Australia after all Recent fault scarps have been identified and mapped.

Links

http://neic.usgs.gov/neis/eqhaz/010126.html USGS site with seismological info including a number of links to other sites of potential interest.

http://www.eeri.org/ Earthquake Engineering Research Institute site with information on damage and post-event investigations

http://mae.ce.uiuc.edu/ Mid America Earthquake Center site with discussions of similarities of this event to the New Madrid earthquakes, plus information on a post disaster reconnaissance team being sent by the Center.