

PROPERTY FIRE PROTECTION FOR NEW SCHOOL BUILDINGS — COST-BENEFIT AND PILOT STUDY

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ABSTRACT

This paper presents the findings of a cost-benefit and pilot study that is aimed at developing a viable fire protection system to reduce the potential property loss in new school buildings in Victoria.

As part of the study, school fire statistics from Victoria, NSW, New Zealand, USA and UK were examined and a cost-benefit model developed. Fire protection systems including smoke detection and sprinklers were examined for their potential benefits in reducing fire losses. The benefits and costs of the each system were analysed. It was found that systems designed and installed in accordance with the relevant Australian Standards do not represent viable solutions from a cost-benefit viewpoint. It was evident that for a system to be viable, it must be tailored specifically for the school buildings by lowering the costs. Consequently a tailored sprinkler system was developed that could be viable for protection of school building.

Subsequent to the cost-benefit study, a pilot project was undertaken whereby the tailored sprinkler system was designed and installed in a new school.

At the completion of the construction of the school, a post-occupancy evaluation was carried out on the pilot project. It was found that the total cost of the system installed was substantially higher than the break-even point for a viable solution. This was due to a combination of factors that arose during the project. Many useful lessons have been learnt from the process that allows any future implementation to be significantly improved.

Despite the failure of the pilot project to achieve the low cost envisaged in its development, the tailored sprinkler system remains a viable concept. The key lesson from the pilot study is that, for it to be viable and be successfully implemented, more effort must be invested by various stakeholders to lower the costs. All stakeholders must also share the same objective, and cooperatively work and strive to achieve the same outcome

INTRODUCTION

Victoria's public schooling system represents one of the largest asset portfolios in Australia. In 2004, there were 1,618 schools across the state of Victoria [1].

Primary schools usually contain only single storey buildings; and secondary schools may contain one or two storey buildings. Three or more storey school buildings in Victoria are rare. For these one and two storey school buildings, apart from fire hydrant protection, the Building Code of Australia (BCA) [2] generally does not require smoke detection, sprinkler protection or fire resistant construction.

In 2003 and 2004 there were a number of large fires involving school buildings [3,4]. These focused media and political attention on school fires in Victoria [5-8] and drew in the debate of whether sprinklers should be installed in school buildings [9-15].



In 2005, the Victorian Department of Education and Early Childhood Development (DEECD) commissioned Umow Lai to conduct a fire engineering study to investigate the cost-effectiveness of fire protection for new school buildings. The investigation was initiated based on the recognition that life safety in schools is generally very high. It was aimed at developing an appropriate cost-effective fire protection system to reduce the potential property loss, particularly, in new school buildings which have a higher property value.

This study was conducted in consultation with an expert group, comprising:

- Country Fire Authority (CFA)
- Department of Education and Early Childhood Development (DEECD)
- Metropolitan Fire Brigade (MFB)
- Victorian Coroner's Office
- Victoria Police Arson Squad
- Victorian Managed Insurance Authority (VMIA)
- Victoria University (VU)

SCHOOL FIRE STATISTICS

As part of the study, fire statistics in Victoria, New South Wales [16] and overseas (USA [17,18], UK [19], and New Zealand [20,21]) were examined. The Victorian fire statistics were supplied by MFB, CFA and DEECD. These data provide much of the input for the cost-benefit analysis. The NSW and overseas statistics were examined for comparison purposes and for determining the effectiveness of various fire protection systems.

MFB and CFA Statistics

During the period 2000 to 2004, MFB and CFA attended a total of 429 fire incidents associated with school buildings in Victoria (an average of 85.8 incidents per year).

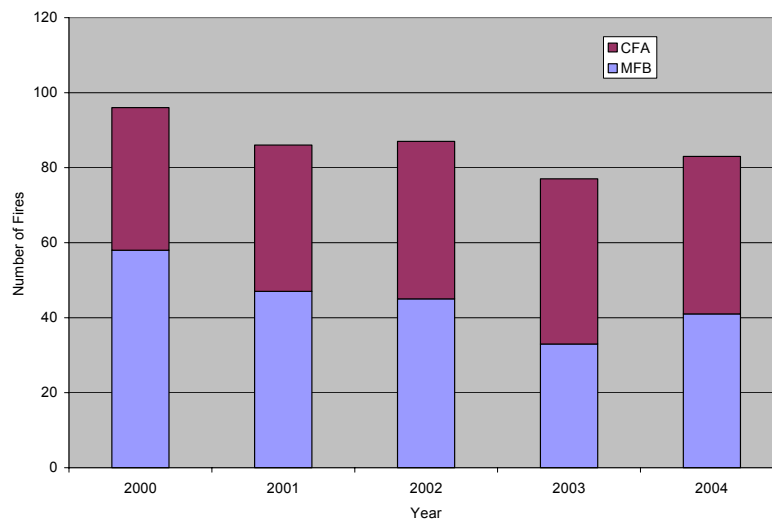


Figure 1: School Fire Incidents Attended by MFB and CFA

The statistics show that a large proportion of the fires were deliberately lit by arsonists.

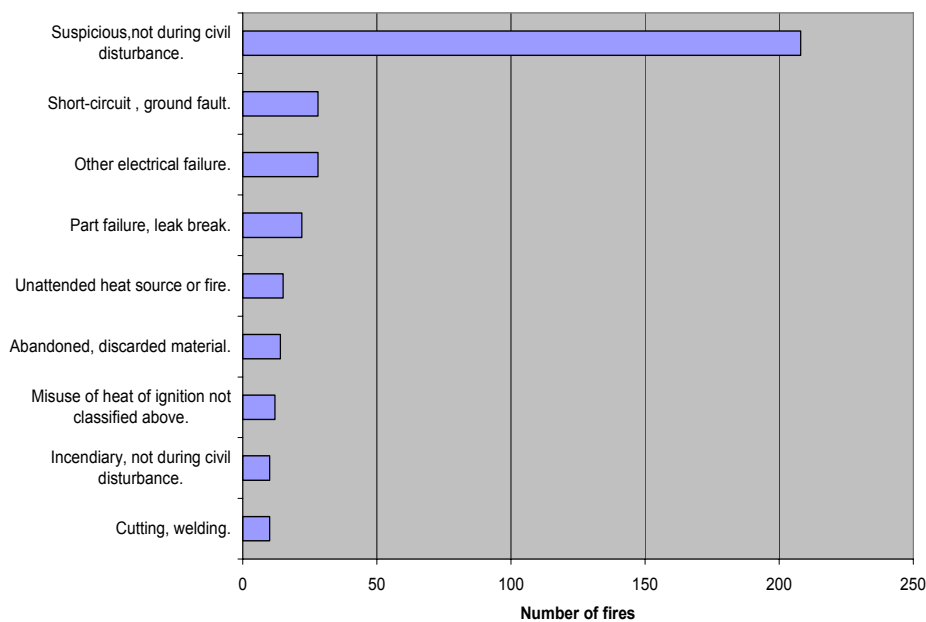


Figure 2: Cause of Fire Start

The extent of fire damage of the fires is shown below.

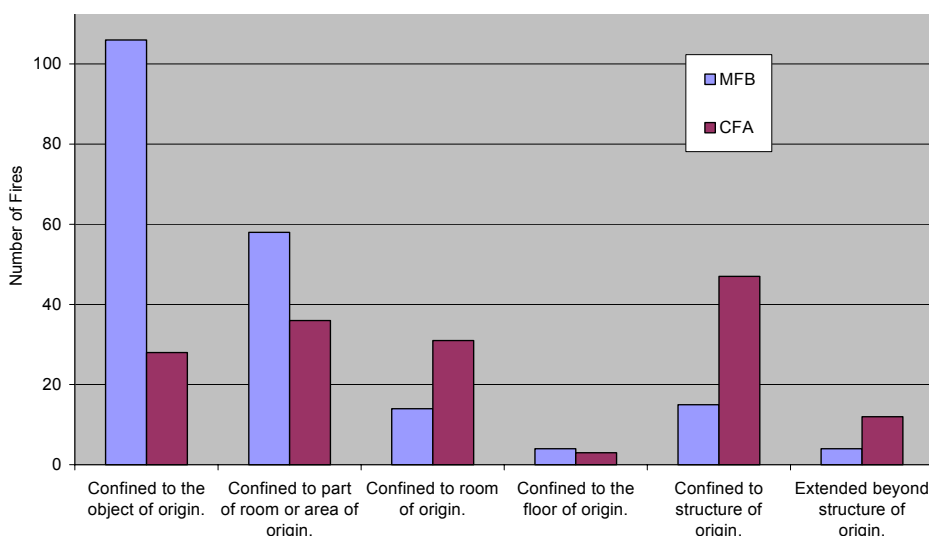


Figure 3: Extent of Fire Damage

If we assume that the extent of damage “*Confined to room of fire origin*” and above are significant fires, this represents 17% of MFB and 58% of CFA school fires. Hence, the number of significant fires” = $(220 \div 5 \times 0.17) + (166 \div 5 \times 0.58) = 26.7$ per year.

During the same period, MFB and CFA estimated direct fire losses totalled \$26.8 million for the school building fires (an average of \$5.4 million per year).

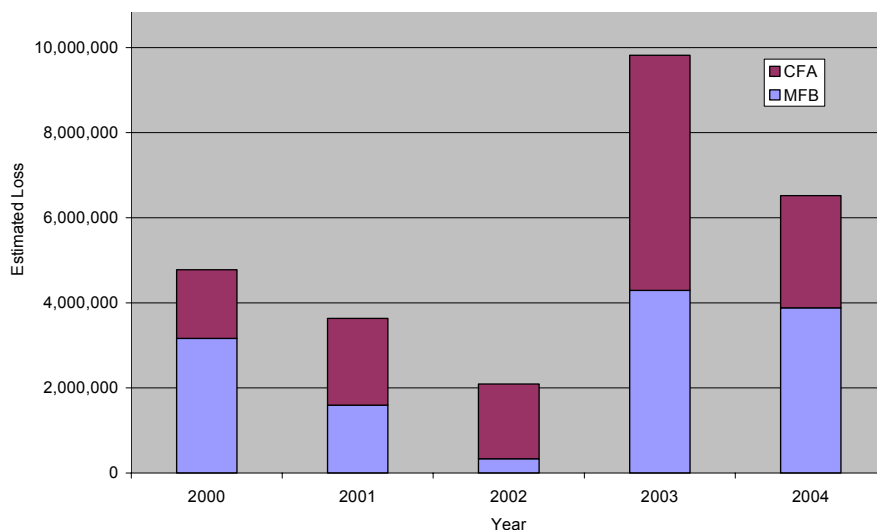


Figure 4: Direct Fire Loss Estimated by MFB and CFA

DEECD Statistics

Whilst the MFB and CFA statistics include all fires attended by the fire brigades, the DEECD statistics contains only significant fires that resulted in clean-up and reinstatement by the Department. These fires incurred a dollar/value loss to DEECD, and are the only relevant fires for cost-benefit analysis.

The statistics show that, DEECD spent a total of approximately \$16 million (historical value) during 2000 to 2005 for clean-up and reinstatement for 119 school fires.

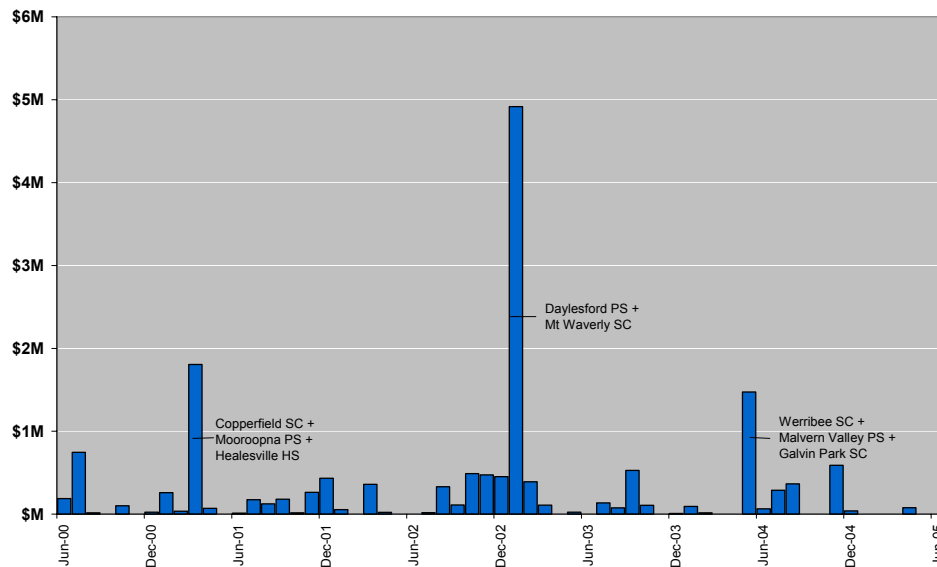


Figure 5: DEECD Monthly Clean Up and Reinstatement

For a total of 1618 state schools, this represents a rate of:

- = 23.8 significant fires per year (this is comparable to 26.7 significant fires per year from the MFB and CFA data).
- = 0.0147 significant fires per year per school

NSW and Overseas Statistics

School fire statistics from NSW and overseas (USA, UK, and NZ) were also examined and the some of the key findings are summarised below.

a) Fatalities and injuries

- There were no fatalities reported in USA during 1996 to 1998 and in 2002. A longer term USA fatality rate is approximately 0.5 fatalities per 1000 fires in unprotected educational buildings (includes tertiary and pre-school).
- Injury rates in USA educational building are 22 per 1000 fires over the period of 1996 to 1998 and 29 per 1000 fires in 2001/02. A longer term injury rate for US Educational building is approximately 25.9 per 1000 fires.
- Only one death has been reported in the past 20 years in NSW schools.

b) Some similarities and differences

- Arson fires are consistently the single most significant source of fire starts (54% of school fires in NSW, 60% in UK, and 52% in USA).
- Similar to the Victorian experience the majority of school fires (about 52%) in the USA are external to the school structure.
- NZ has equivalent population to Victoria but has twice the number of school fires.
- In USA, fires in school buildings occurred predominantly in the toilet areas (28%), and 70% of all fires occur between 0800 and 1600 during the day.

c) Sprinkler and Hydrant Experience

- In UK, schools are not required to be sprinkler protected. However, up to 100 schools have installed sprinklers for property protection and gained insurer premium reductions.
- In NZ, sprinklers are installed in all new schools and large school buildings (over 1,000 m²). This requirement arises from the relatively high number of school fires in NZ.
- In USA, the requirements for sprinklers in schools are not uniform as there are many Authorities Having Jurisdiction across USA. Generally, installation of sprinklers is voluntary and most model building codes in USA allow trade-offs of sprinklers against protected construction.
- NSW fire statistics shows that the major means of extinguishment is water direct from the hydrant in about 3% of fires; and that from either reticulated or static sources with a pump is about 5%. These include fires in open areas, playgrounds and the like. It is unclear what role significant fires (large losses) play in this 8%.

EFFECTIVENESS OF FIRE PROTECTION SYSTEMS

The effectiveness of various systems in reducing fire loss in school building has been examined in a separate study conducted by VU based on USA experience [22]. The findings are summarised below (this is used later in the cost-benefit analysis).

Table 1: Effectiveness of Fire Protection Systems

<i>Sprinklers</i>	x	x	x	x	✓	✓	✓	✓
<i>Detectors</i>	x	✓	x	✓	x	✓	x	✓
<i>Protected Construction</i>	x	x	✓	✓	x	x	✓	✓
Reduction in Fire Loss	0.00	0.12	0.46	0.63	0.64	0.88	0.84	0.85

where: x = not installed, ✓ = installed

COST-BENEFIT ANALYSIS

In the fire engineering study of the fire protection systems, the decision as to whether or not the installation of an additional system is justified for a new school is based on the comparison of its *benefits* and *costs*, in terms of present dollar value, over the life of the school building. The *benefits* and *costs* are calculated as follows:

$$\text{Benefits} = \text{direct benefits} + \text{indirect benefits}$$

$$\text{Costs} = \text{initial installation costs} + \text{running costs}$$

where:

$$\text{Direct benefits} = R \times P \left[\sum_{n=1}^L \frac{D}{(1-d)^n} + \sum_{n=1}^L \frac{C}{(1+r)^n} \right]$$

$$\text{Running costs} = \sum_{n=1}^L \frac{M_n}{(1+r)^n}$$

and:

- R = reduction in fire loss due to the effects of the additional system
- P = probability of significant fires (= 0.0147 per year per school, based on DEECD statistics)
- D = average property damage due to a significant fire (without the additional system)
- C = average clean-up/reinstatement due to a significant fire (without the additional system)
- M_n = running costs including maintenance, replacement, damage arising from of the system during year n
- L = life of the school building (assumed 60 years)
- d = annual rate of depreciation of property value (assumed 2.5%)
- r = annual discount rate = interest rate - inflation rate (assumed = 8% - 2.5% = 5.5%)
- n = year

Indirect benefits are associated with reduction in indirect losses of fires due to the effects of the additional system. These losses include trauma caused to students, teachers and parents, disruption to schools, loss of resources, historic memorabilia etc which cannot be readily measured in dollar value. A recent study was made of these aspects in a qualitative manner in NZ [21]. It was argued in [15] that ancillary and indirect damage associated with the fires are three times that associated with the lost of building assets.

It is argued that a system that reduces the impact of fire will reduce both the direct fire losses and the indirect losses. Accordingly, a system that provides *direct benefits* will provide *indirect benefits*. In this study, no attempt is made to calculate *indirect benefits*. However if we conservatively assume that *indirect benefits* approximately equal *direct benefits*, then it could be argued that the total *benefits* would be approximately 2 x *direct benefits*.

In order to take *indirect benefits* into account, the following acceptance criteria for a protection system can be set:

$$\begin{array}{ll} \text{costs} < \text{direct benefits} & \text{system is } \mathbf{viable} \\ \text{direct benefits} < \text{costs} < 2 \times \text{direct benefits} & \text{system is } \mathbf{plausible} \end{array}$$

Estimating *Benefits*

a) Reduction in fire loss, R

R is calculated based on USA experience as discussed earlier. For smoke detection and sprinkler systems, the reductions in fire loss are (see Table 1):

$$R_{\text{detectors}} = 0.12 \quad \text{and} \quad R_{\text{sprinklers}} = 0.64$$

b) Property damage, *D*

The extent of damage during a significant fire (“confined to the room of origin” or beyond) is estimated based on MFB and CFA statistics and assuming a ratio of damage to the room for each category.

Table 2: Extent of Fire Damage from Combined MFB and CFA data

Extent of damage (category)	Portion	Assumed damage to room	Portion Adjusted Damage
3. Confined to room of origin	0.35	0.5	0.173
4. Confined to the floor of origin	0.05	1.0	0.054
5. Confined to structure of origin	0.48	1.5	0.715
6. Extended beyond structure of origin	0.12	3.0	0.369
Total	1.00		1.312

This estimate gives an average of damage of 1.312 rooms due to a significant fire as shown in the table above.

Based on DEECD’s costs for new buildings, average value of one room is approximately \$155,000. Using this value and the estimated damage:

$$D = 1.312 \times \$155,000 \approx \$203,000 \text{ per significant fire}$$

c) Clean-up/reinstatement, *C*

During 2000-2005, DEECD spent a total of \$19.8 million (Net Present Value) for clean-up and reinstatement for 119 fires. This gives an average clean-up and reinstatement of:

$$C = \$19,800,000 \div 119 \approx \$167,000 \text{ per significant fire.}$$

c) Benefits

Using a net present value calculation over 60 years life of a new school, the average value of fire losses is:

$$= P \left[\sum_{n=1}^L \frac{D}{(1-d)^n} + \sum_{n=1}^L \frac{C}{(1-r)^n} \right] \approx \$137,000 \text{ per new school}$$

The *direct benefits* are multiples of the above by the corresponding *R* values. Hence, for smoke detection and sprinkler systems:

$$\begin{aligned} \text{direct benefits}_{(\text{detectors})} &\approx \$16,000 \\ \text{direct benefits}_{(\text{sprinklers})} &\approx \$87,000 \end{aligned}$$

The *direct benefits* of other systems or combinations of systems can be determined using the corresponding *R* values in Table 1.

When *indirect benefits* are included, the total *benefits* become:

$$\begin{aligned} \text{benefits}_{(\text{detectors})} &\approx \$32,000 \\ \text{benefits}_{(\text{sprinklers})} &\approx \$174,000 \end{aligned}$$

Estimating Costs

a) Fire Protection Systems Examined

- SM1* = Smoke detection systems in accordance to AS1670 [24] (10 m spacing).
- SM2* = Smoke detection systems in accordance to extended spacing in the BCA and AS1668.1 [25] (20 m spacing).
- SP1* = Sprinkler system in accordance to AS2118.1 [26] (light hazard)
- SP2* = Sprinkler system in accordance to AS2118.4 [27] (residential, light hazard spacing)
- SP3* = A “non-standard”, tailored sprinkler system based principally on *SP2*, but with various changes made to lower the cost of the system. The system may be supplied from either the main domestic water reticulation or fire hydrant system. Sprinklers are excluded from areas with low fuel load such as toilets, change rooms (bath or showers), passageways, corridors, and sports courts. No FIP or Alarm Signalling Equipment (ASE). The system will be connected to DEECD monitoring service with a flow switch in each building. The system may be installed by a plumber.

All the sprinkler systems considered include flush mounted sprinklers (concealed heads) to minimise deliberate damage of the sprinklers by students.

b) Cost Estimates

For the purpose of the analysis, a new school in Victoria constructed prior to the study was used for estimating the costs of the various fire protection systems. It contains 6 single-storey buildings and has total floor area 5,280 m².

Each of the systems examined was designed for the school and the costs estimated. The costs are summarised below.

Table 3: Costs of Fire Protection System

<i>Fire protection system</i>	<i>Initial installation costs (x\$1000)</i>	<i>Running costs (x\$1000)</i>	<i>Total costs (x\$1000)</i>
<i>SM1</i>	49	93	142
<i>SM2</i>	21	80	101
<i>SP1</i>	179	106	286
<i>SP2</i>	149	106	255
<i>SP3</i>	63	9	72

The following assumptions were made in the cost estimates:

- Initial Installation Costs* — All installation costs include allowances for an operation and maintenance manual, certification, testing & commissioning.
- Running Costs* — Running costs include allowance for maintenance, replacement of parts, alarm signal monitoring, damage arising from of the system.
- Smoke detection systems have a life of 20 years, and will need to be replaced in the 20th and 40th years. These are calculated as present values of the installation costs at years 20 and 40 and respectively.
- Sprinkler systems have a life of more than 60 years and no replacement will be needed. However allowance is made for water damage due to attack on sprinklers.
- The tailored sprinkler system is connected to DEECD monitoring service and includes less frequent maintenance checks

Cost-Benefit Comparison

Table 4: Cost-Benefit Comparison

<i>Fire Protection System</i>	<i>Direct Benefits (x\$1000)</i>	<i>+Indirect Benefits (x\$1000)</i>	<i>Fire Protection System</i>	<i>Costs (x\$1000)</i>	<i>Viable</i>	<i>Plausible</i>
<i>Smoke Detection</i>	16	32	SM1	142	No	No
			SM2	101	No	No
<i>Sprinkler</i>	87	174	SP1	286	No	No
			SP2	255	No	No
			SP3	72	Yes	Yes

The comparison shows that fire detection and sprinkler systems designed in accordance with Australian Standards do not compare favourably from a cost-benefit viewpoint. However, it is possible to tailor a sprinkler system to be a viable solution by reducing its costs to a level below its *direct benefits*.

PILOT STUDY

Subsequent to the cost-benefit study, a pilot project was undertaken by DEECD whereby the tailored sprinkler system SP3 was designed and installed in a new school. The school contains six single-storey buildings with a total floor area of approximately 4500 m². The sprinkler system was designed by the design team for the school project and installed by the builder as part of a total tender for the construction of the school.

At the completion of the construction, a post-occupancy evaluation was carried out.

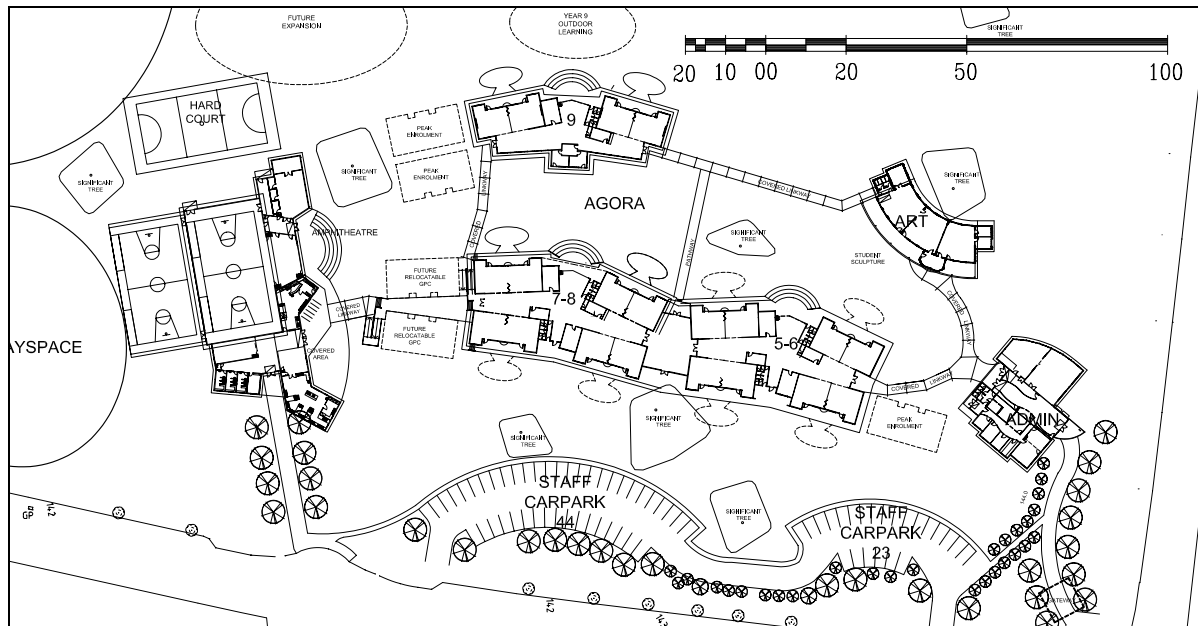


Figure 6: Pilot Study School

Actual Cost of the Sprinkler System

The post-occupancy evaluation revealed that the total cost to DEECD for the sprinkler system in the pilot study was approximately \$154,000. This included:

Accepted tender price for installation of sprinkler system ^a	\$104,000
Additional cost for redesign and material change ^b	\$28,000
Additional cost for gas isolation valve ^c	\$4,000
Additional cost for visual alarms ^d	\$5,000
Running cost (prevent value over 60 years) ^e	\$13,000
Total	\$154,000

- a) This is the price from the builder who won the tender for the construction of the school. The tender was selected based on various factors, and may depend little on the sprinkler system.
- b) The additional cost of \$28,000 was associated with redesign of the sprinkler system due to a change in piping material. This occurred during construction phase when the builder reported that the piping materials, on which the original tender was based, were no longer available. The system was redesigned using CPVC piping which carried a higher material cost.
- c) The additional cost of \$4,000 was associated with an inclusion of a connection to shut down gas supply in the event of sprinkler activation.
- d) The additional cost of \$5,000 was associated with visual alarms requested by the Fire Brigade, as part of the regulatory process, to help the brigade locate the building in alarm.
- e) The maintenance cost proposed by an external contractor to conduct pressure and flow tests on the sprinkler system was about \$600/year. This is also higher than the value used in the cost-benefit analysis.

Cost-Benefit Comparison

In the pilot project, the cost to DEECD for the sprinkler system was substantially higher than the *direct benefits* (\$87,000), but lower than the total *benefits* including *indirect benefits* (\$174,000), as estimated in the cost-benefit analysis. Based on the criteria set in the cost-benefit study, it represents a *plausible* solution by not a *viable* solution. This is the case even without the additional costs incurred in items (b) to (e). In other words, the pilot project failed to achieve the low cost envisaged during the development of the tailored system.

Some of the costs of sprinkler system could be off-set by savings resulting from the rationalisation of hydrant system, which is shown in the NSW statistics to be under-utilised. Due to the presence of the sprinkler system, some shortfalls to the hydrant coverage were approved for the pilot study school. Unfortunately, the costs of the hydrant system were not itemised in the tender package and the savings could not be quantified.

Issues and Lessons Learnt

Issues and lessons learnt from the pilot study were:

- The project objective was not being clearly understood by the parties involved in implementing the system. For the system to be cost-effective and be successfully implemented in school buildings, more effort must be invested by various stakeholders to lower the costs. All stakeholders must share the same objective, and cooperatively work and strive to achieve the same outcome
- The designers, authorities, builder, installer and maintenance suppliers have worked only with “standard” systems. Working with a “non-standard” tailored sprinkler system raised various issues during design and construction phases due to unfamiliarity with the system.
- Any future use of a tailored system would require a detailed design guide to further assist the design team and stakeholders. Effective communication amongst the design team and stakeholders would also be essential for its success.
- Pricing by the builder for the tailored system was likely to err on the conservative side also due to unfamiliarity or lack of experience with such system. Increase use of the tailored sprinkler system would likely lead to more realistic pricing for the system.
- Significant cost variations arose during the pilot project. This was one of the key factors that significantly affect the cost-effectiveness of the system. Improved project delivery process would reduce the variations and increase the viability of the system.
- Rationalisations of the fire hydrant system, as part of the sprinkler solution, could represent a significant opportunity to increase the cost-effectiveness of the sprinkler solution.

CONCLUSIONS

A cost-benefit model has been developed for determining the viability of fire protection for new school buildings. The break-even points for achieving cost-effectiveness for various systems have also been established.

From a property protection viewpoint, it was found that smoke detection systems and sprinkler systems designed according to the relevant Australian Standard do not present viable cost-effective solutions. However, it is possible to tailor a “non-standard” sprinkler system to lower its costs below the break-even point to achieve cost-effectiveness. A tailored sprinkler system has been proposed in this paper and shown to be a viable solution.

The tailored sprinkler system was installed in a new school as a pilot study. However, the post-occupancy study carried out on the pilot study showed that the costs of implementation were significantly higher than that envisaged during its development. This was due to various unforeseeable factors that occurred during the design and construction phases of the school project. Many useful lessons have been learnt from the process that allows any future implementation to be significantly improved.

Despite the pilot project failing to achieve the low cost envisaged during the development of the tailored system, it remains a viable concept. To succeed, more effort must be invested by various stakeholders to lower the costs. All stakeholders must also share the same objective, and cooperatively work and strive to achieve the same outcome. Further cost savings may also be achieved by rationalising other fire-protection systems to achieve overall cost-effectiveness for fire protection of new school buildings.

REFERENCES

1. “Annual Report 2003-2004”, Department of Education and Training, October 2004.
2. Building Code of Australia Class 2 to Class 9 Buildings”, Australian Building Codes Board, 2008.
3. “Post Incident Summary Report, Malvern Valley Primary School, Abbotsford Avenue, Malvern East, Fire Date: March 5, 2004”, MFB Fire Investigation & Analysis Unit.
4. “Post Incident Summary Report, Mount Waverley Secondary College, 98 Stephenson Road, Mount Waverley, Fire on 28 January 2003”, MFB Fire Investigation & Analysis Unit.
5. “School Year off to Fire Start”, Herald Sun, 29 Jan 2003.
6. “Fire destroys Part of Mount Waverley School”, The Age, 28 Jan 2003.
7. “Start of Term Fire Shocks School’s Pupils, Teachers”, The Age, 29 Jan 2003
8. “Liberals Win Fight on Secrete School-Fires Report”, 22 Jun 2006
9. “School Sprinklers Advised”, Herald Sun, 29 Jan 2003.
10. “A Sprinkler System in Every School...”, Herald Sun, 30 Jan 2003.

11. “Coroner Launches Probe into Spate of School Fires”, The Age 21 Jun 2004
12. “Fire Chief Attacks School Safety”, The Age 21 Jul 2004
13. “Scare-Mongering is No Way to Deal with School Fire Risk”, 23 Jul 2004
14. “MFB & CFA Position Paper on Fire Risk Management in Schools”, MFB & CFA, 13 August 2004.
15. Clancy, P., Satyen, L, Thomas, I., “Property Protection: School Buildings”, Proceeding, 5th International Conference on Performance-Based Codes and Fire Safety Design Methods, Luxemburg, 6-8 October 2004.
16. “New South Wales Fire Brigades, Annual Statistical Report 2001/02”, NSW Fire Brigades, 2003.
17. “School Fires”, U.S. Fire Administration/National Fire Data Center, Topical Fire Research Series, Volume 2 – Issue 9, December 2001.
18. “School Fires”, U.S. Fire Administration/National Fire Data Center, Topical Fire Research Series, Volume 4 – Issue 6, December 2004.
19. “Fire Statistics, United Kingdom, 2003”, Office of the Deputy Prime Minister, London, March 2005.
20. “Emergency Incident Statistics, 1 July 2003 – 30 June 2003”, New Zealand Fire Service.
21. “School Fires in New Zealand, Economic and Social Analysis”, NZIER and Croydon Consultants Ltd, February 2002.
22. Thomas, I, “Effectiveness of Fire Safety Components and Systems”, Journal of Fire Protection Engineering, Vol. 12, May 2002, pp 63-78.
23. Holborn P. G., Nolan P. F., Golt J. and Townsend N., “Fires in workplace premises: risk data”, Fire Safety Journal, Volume 37, Issue 3, April 2002, Pages 303-327.
24. “AS1760.1, Fire detection, warning, control and intercom systems, Fire”, Standards Australia.
25. “AS1668.1, The use of mechanical ventilation and air handling in buildings, Fire and smoke control in multi-compartment buildings”, Standards Australia.
26. “AS2118.1, Automatic fire sprinkler system, General requirements”, Standards Australia.
27. “AS2118.4, Automatic fire sprinkler system, Residential”, Standards Australia.
28. “AS2118.5, Automatic fire sprinkler system, Domestic”, Standards Australia.