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The NSW demountable classroom: An analytical study to improve this radical building solution for education

Ben Slee[1]and Richard Hyde[2]
[1,2] University of Sydney, Sydney, Australia
ben.nj.slee@gmail.com, richard.hyde85@gmail.com

Abstract: The NSW demountable classroom continues to fulfil the function it was designed to fulfil and is radical because, unusually, it has always been capable of adaption. However in recent years aspects of the system have become obsolete. The technology exists to adapt it and turn it into a high performance building typology. This paper adopts a qualitative methodology based on the Building Performance Research Unit's (BPRU) concept of buildings as a series of open systems. Using contemporary documentary evidence, open ended structured interviews and detailed physical inspections the first part of the paper shows that the demountable classroom has played and continues to fulfil an important and significant role in the provision of teaching accommodation across the state as it was originally designed to do. The second part of the paper considers the changing perception of the demountable classroom in the context of the concept of obsolescence. The paper concludes by showing that the demountable classroom was and remains a radical building solution, that is mistakenly maligned, and offers the communities and government of New South Wales an opportunity to develop a high performance, adaptable and low carbon piece of education infrastructure.

Keywords: Demountable classrooms, Obsolescence, Building performance

1. Introduction

This paper adopts a qualitative methodology based on the Building Performance Research Unit's (BPRU, 1972) concept of buildings as a series of systems with a social purpose within a larger social context. The analysis uses various sources of data including contemporary documentary evidence, open ended structured interviews, detailed physical inspections and the parliamentary record of political debate, Hansard (Hansard NSW).

Demountable classrooms account for 12% of all government classrooms in NSW. A detailed literature search by the authors outlined in previous papers has not found a detailed study of the building performance or internal environmental quality (IEQ) of demountable classrooms in NSW or more generally across Australia, and limited international research into the performance of demountable classrooms (Slee and Hyde, 2014; Slee *et al.*, 2014a; Slee and Hyde, 2015).

In the first part of the paper an analysis of the data shows how the classroom system has played a consistent and important role in allowing a succession of governments to implement new policies in response to changing demographics, new pedagogical theories and the corresponding expectations of the population. The analysis also shows how, despite the stated need for and purpose of the demountable classroom system remaining constant, the communities' perception of the demountable classroom has changed from being innovative to inadequate.

The second part of the paper considers this change in perception in the context of Pinder and Wilkinson's (2000b) concept of building obsolescence, the gap between design intent and user expectations and the implications for the perception of utility.

The paper concludes by showing that the demountable classroom system was and remains a radical building solution that offers the communities and government of New South Wales an opportunity to develop a high performance, adaptable and low carbon piece of education infrastructure. The critical issues that must be addressed for this opportunity to be realised are identified.

2. Research Framework

Buildings are an intrinsically complex system and exist within other complex environmental and social systems. The framework proposed by the BPRU (1972) provides a strategy for understanding, categorising and evaluating the sub- and meta- systems that come together to create the whole.

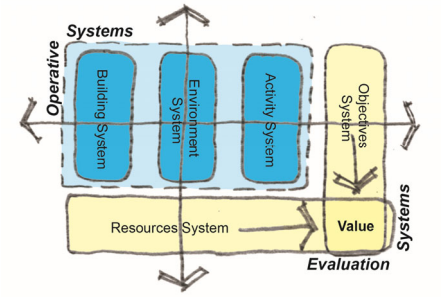

Figure 1: The Building Performance Research Unit framework of Systems

The BPRU framework defines five categories of "system" (Figure 1), the first three of which can be thought of as "Operative Systems" and the last two as "Evaluation Systems". The Operative Systems are the "Building System", "Environmental System" and "Activity System". The Building System deals with the fabric of the building and the method of construction, manufacture and deployment. The Environmental System covers the strategies that are designed to create a comfortable internal environment. The Activity System are the activities that take place in the building, in this case teaching and learning.

The Evaluation Systems evaluate the Operative Systems in terms of the purpose of the building as a social entity, the "Objective System", and the means used to meet those objectives, the "Resources System". Thus the framework creates a means of understanding the economic, social and environmental value of the building. This paper follows this approach to analyse the existing demountable classroom and identify a pathway to improving this radical building typology.

3. Objectives system: a continuous need and purpose

The description of the need for, and purpose of, the demountable classroom system in NSW has remained constant over the five decades that they have existed. In his pamphlet describing the changes and advances in the design of NSW schools between 1962 and 1972 Underwood (1972) explains that the new "divisible classroom" was designed by the Department for Public Works in 1965 "[to provide]

- virtually instant accommodation
- temporary facilities in special areas
- augmentation of existing schools
- a convenient means of adding to and later subtracting from existing schools."

Today the NSW Department for Education statement on Demountable classrooms (NSW Government, 2014) explains that the purpose of the demountable is to:

- provide accommodation for peak enrolments
- meet accommodation needs in schools from increased enrolments
- meet emergency needs as a result of fires or natural disasters
- meet needs arising from capital works or maintenance projects in schools.

The interviewees tell a similar story, over the 35 years of their collective experience, explaining that the need for and purpose of the NSW demountable classroom has been and remains the provision of emergency accommodation and accommodating fluctuating school populations.

Government Education Policy's effects on the demand for classrooms

Government policy has been facilitated by the availability and utility of the demountable classroom system. Over the last 50 years a succession of policy decisions have increased the number of classrooms needed in schools. In 1961 the Wyndham report was published and became the Education Act of 1962. The act increased the school leaving age by a year to 16 years old and expanded the number of subjects to be taught to create a broad liberal education for pupils of all abilities. In 1979 the Government cited the continuing drive to reduce class sizes as a reason for increasing the use of demountable classroom buildings (Hansard14/08/1979). Between 2004 and 2007 the Government instigated a specific policy for reducing the size of classes in Kindergarten, year 1 and year 2 to 20, 22 and 24 pupils respectively. In 2012 the school leaving age was raised further to 17 years old increasing the compulsory years at secondary school from 4 to 5. Each of these policy changes significantly increased individual school populations.

Pedagogy has also changed significantly since the demountable school was originally introduced from a "chalk and talk" approach, led by a teacher instructing pupils sitting in rows, to a student led approach to learning that requires "break out" spaces for group work and more traditional class arrangements for instruction. The development of pedagogy has led to the need for larger more flexible classrooms to accommodate the new teaching methods.

Demographics

The initial driver for developing the rapidly deployable classroom was the rapid growth in the NSW population between 1945 and 1971/72 and the corresponding growth in school populations. Associated with the growing population was the risk and later the reality of changing demographics within suburbs as young families matured. Burkhardt (1980) explores this problem in his thesis "Planning for the

provision of school facilities in new communities in New South Wales" in which he illustrates that peak enrolment of a school is likely to be substantially higher than the long term average. Burkhardt compared the changing school demographics in areas of public housing projects and private housing developments. His data shows that in private housing developments, with considerably more diverse types of household than public housing projects in the 1970's, it may take 15 years for the population of a new school to reach its peak and more than 25 years for the schools population to stabilise around the long term average.

When the rate of overall population growth in NSW became considerably more moderate after about 1980 the challenges raised by changing demographics in suburbs continued and have been raised regularly in the NSW Parliament. Examples include the development of complete demountable schools in Bateau Bay, Lake Maquarie in 1977 (Hansard24/03/1977), Baulkham Hills in 1979, and more recently in Chatswood (Interviewee E). In 1983 the construction of the Earing power station in Morriset led to a sudden increase in the local school population and the use of demountables (Hansard 01/12/1984).

The challenge of fluctuating populations and demographics is illustrated by a debate in parliament in 1989 about the closure of public schools in Mosman where the local school was no longer sustained by the changing demographic of the local population. According to the debate 197 schools were closed across NSW between 1976 and 1988 (Hansard 11/04/1989).

Core plus Schools

In the 1970's, 80's and 90's the NSW government had a policy of developing "core plus" schools where about 60 or 70% of the school is built as permanent facilities and 30% of classrooms are demountable (interview B) (Underwood, 1972). The concept allows teaching capacity in these schools to be adjusted rapidly to accommodate changing demand.

Emergency needs

There are many examples of demountable classrooms providing the NSW Government with school accommodation following arson, accident or natural disaster. The NSW Government maintains an entire demountable school in reserve for use in emergency situation such as these (interview D).

4. Building system: construction

Classrooms consist of 4 or 5 units approximately 8.8m (L) x 2.4m (W) x 3.3m (H). One of the primary objectives for the design of the demountable classroom system is that the units should be easy to transport. The primary objective of the design was to provide a rapidly deployable and easily transportable classroom building (Underwood, 1972). This leads to a number of key design decisions based on

- Maximum dimensions permissible for road transport without an escort
- Maximum transportable weight and deployment weight
- Deployment method
- The need for a robust modular construction system

This means that they should be robust and relatively light leading to the use of lightweight framed construction. The original drawings and the physical survey of both the mk 1 and mk 2 classroom designs show limited insulation, well below the current statutory regulations, and considerable thermal

bridging through the primary and secondary steel frames . The primary frame of the Mk. I and Mk. II classrooms is a substantial steel frame described by interviewees as “bomb proof” (Interview A). The maintenance programmes at Cessnock and Golburn jails (Corrective Services Industries) strip the old classrooms back to the primary frame and rebuild them.

Deployment Method

The original proposal for deploying Mk. I classrooms was to use jacks (Underwood, 1972). This strategy has been superseded by the use of cranes. Mk 1 classrooms were designed without lifting points and so chain slings are used under the roof overhangs. Mk. II classrooms were designed with lifting points attached to the top of the vertical steel posts. Recently a policy of modifying the Mk I classrooms to add lifting points has been implemented. These are additional steel flanges welded to the existing frame during substantial refurbishment exercises.

Modular construction

The demountable classroom system has been conceived as a modular system at the macro and micro level. At the macro level classrooms, libraries and office buildings can be delivered to any site in NSW to create an entire school or augment existing schools. The classrooms themselves are made from 4 units and the walls in each unit are made from a variety of wall modules designed to accommodate the various functions the system is intended to accommodate. The Mk II panels were designed to facilitate the rapid interchange of panels and the adaption of buildings. In practice wall panels are rarely changed, typically only during substantial refurbishment work.

The ambition to create a system of interchangeable building modules was also thwarted through perhaps the most mundane of processes: The classroom modules are fixed together by bolted connections through steel plate flanges on the outside of the classrooms. For expediency and ease of installation on the initial site these were drilled and bolted on-site during the first deployment of a unit (Interview C/Observation), a very practical approach by the installation team that ensured that the holes on each adjacent classroom unit lined up. Unfortunately this has resulted in a situation where only the modules placed together during the first deployment have holes that line through so each classroom unit can only ever be erected in its original configuration!

Figure 4: Deployment of a Mk I demountable classroom module.

5. Environmental System

Internal comfort does not appear to have been a priority objective in the original design brief. The lightweight poorly insulated building fabric is unsuitable for creating an "acceptable" internal thermal environment, particularly in the more extreme climates away from the NSW coast. Buildings that are constructed using lightweight construction systems closely follow, or exceed, the external diurnal temperature profile (Pearlmutter and Meir, 1995; Sugo, 2009; Cardinale *et al.*, 2010).

Originally three passive strategies were employed to try and maintain comfort inside the classroom: shading the windows, considerable opportunity for cross ventilation through opposing opening windows and the use of fly roofs in particularly hot climates. Shading also reduces internal glare. In 2003 active environmental control was introduced to all demountables (Hansard 8/09/2003) and has superseded the fly roof. The current specification of the AC systems is two 6.5KW split cycle systems per classroom.

6. Resources system

Buildings have a local and global environmental cost as well as an economic cost. At a local level the simple pad foundations mean that there is a minimal disruption to the local flora and that when the building is removed the site quickly returns to its natural state. The rapid installation and removal also benefits the school and local community by obviating the need for a construction site.

The lightweight construction is relatively low in embodied energy although no doubt it can be reduced further. The robust construction and the ability to relocate the classrooms means that the resources embodied in the classrooms benefit multiple communities and reduces the under-utilisation of and associated redundancy in the State's education infrastructure. The NSW government owns around 6000 of these classrooms. Assuming conservative construction cost of about $3,000/sq.m the equivalent permanent classroom would cost about $240,000 so the 6,000 demountables (NSW Government, 2014) the government owns represent considerable value on the basis of a replacement cost.

7. Value: societies' changing expectations

Community's expectations of how and in what condition their children are educated have changed over the 50 years the demountable classroom has existed. Society's understanding of developments in pedagogy and our understanding of the significance of comfort is informed by experience, debate in the media, significant reports from government and universities, and political debate within and with governments. This discussion has led to a reduction in class sizes and a move to child led learning. As one interviewee observed: "a 21st century classroom is unrecognisable compared to a 20th century classroom" (Interview E).

In the 21st century the community expects the process of education to be interactive and engaging rather than being passively received and absorbed by rows of children. This new approach to the process of educating children places new demands on the spaces used for educating children.

Thermal expectations have also changed. A number of interviewees suggested that the provision of air-conditioning in classrooms is expected rather than considered to be the exception (Interviews B, C) as air-conditioning use in homes and other places has increased. A finding also observed in research by de Dear et al (2014). In the 17 years between 1994 and 2011 the use of mechanical cooling systems in Australian households changed from being the exception, 32% (Australian Bureau of Statistics, 2010) to common, 73% (Australian Bureau of Statistics, 2011).

The issue of temperature in demountable classrooms was first raised in parliament in 1980 by an MP praising the facilities at the Bateau Bay Demountable Primary School but observing that *"heat in the classrooms in the summer causes problems"* (Hansard 24/11/1980). In 1984 an Adjournment Debate was held in parliament concentrating on the possibility that poor indoor environmental quality (IEQ) could disadvantage the children and teachers who are trying to learn and teach in those spaces (Hansard 02/05/1984). Later the same year the MP for Hawksbury suggested that

> "The higher range of temperatures creates conditions in which primary and infant schoolchildren cannot continue to learn and receive the benefit of their schooling." (Hansard 02/05/1984).

In 2002 Professor Vinson highlighted the issue of temperatures in demountable classrooms in his report on the provision of public education in NSW (Vinson *et al.*, 2002). In 2003 the Government announced that all demountables would be fitted with air-conditioning.

8. The concept of obsolescence

Burton (1933) and more recently Pinder and Wilkinson (2000a) argue that the criteria for the assessment of building performance changes through time as our expectations and society adapt to improvements in construction methods and new technology. They suggest that buildings that continue to meet the objectives they were designed to fulfil may become obsolete because the objectives are no longer aligned to the expectations of the communities they were designed to serve: "Occupant expectations are the essential characteristic of obsolescence" (Pinder and Wilkinson, 2000a).

Pinder and Wilkinson (2000a) argue that buildings are utilities rather than assets and that obsolescence is a measure of their changing usefulness (utility) over time. Following Burton (1933), Pinder and Wilkinson (2000b) argue that there are two classes of causation for obsolescence:

- Locational (extrinsic) causes (e.g. changing demographics, population movement or density and changing climate)
- Building performance (intrinsic) causes (e.g. the thermal performance of the building)

Perception of quality: dawning obsolescence

When the first demountables were introduced they were regarded as a high quality modern innovation. The design won a Certificate of Merit in the Prince Philip Awards for Australian Design in 1968. In 1976 the then Minister for Education countered concern about demountables calling them "excellent accommodation" (Hansard 11/11/1976) and later "*of first-class quality."* (Hansard 01/12/1976)

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In 2002 Professor Vinson (Vinson *et al.*, 2002) dedicated an entire chapter of his report "Inquiry into the provision of public education In NSW" to the significance of the built environment on the quality of education and academic achievement in schools. The report explains that

> "the quality of school buildings and their surrounds can also be a potent symbol of the regard (or otherwise) in which public education is believed to be held by governments and the community"

In a section dedicated to the demountable classroom he notes that

> "Demountables have been the subject of incessant criticism throughout the Inquiry. …..[in] the absence of air conditioning they are too hot; …. their insubstantial character detracts from the appearance and confirmed identity of a school."

Using Pinder and Wilkinson's categorisation of obsolescence the relocatable classroom was specifically designed to avoid the locational, extrinsic causes of obsolescence by being relocatable, possibly with the exception of tight inner city sites (interview E). The second-class, intrinsic building performance causes, have been shown to be a fundamental problem for the building typology.

Over 50 years the demountable classroom has moved from being perceived as a design innovation to "a pejorative" (interview B). They are widely perceived as providing second class teaching accommodation. this is a view exemplified by a debate in the NSW parliament in 2003 with a motion calling for the House to acknowledge *"that the learning environment of a permanent classroom in regional New South Wales is a better learning environment than a demountable classroom." (Hansard 8/09/2003).*

The community's changing perception of what is an acceptable thermal environment and our increasing knowledge of the importance of internal environmental quality (IEQ) on the efficacy of teaching and learning (Mendell and Heath, 2005) appears to be the primary cause of the perception that the demountable classroom is sub-standard or obsolete. Tight urban sites and the flexibility of the classroom spaces are two other issues that may lead to a degree of obsolescence.

9. Opportunities for adaption: A high performance building typology

The concept of obsolescence is implicit in the BPRU framework of operative systems and evaluation systems. The work of Pinder and Wilkinson makes this explicit and highlights opportunities for positive change within the meta-system framework to improve the operation of the building in response to changing social expectations, the evaluation systems. Kieran and Timberlake (2004) and Richard (2006) have argued that the industrially produced relocatable building systems provide a more economic construction method and a solution to obsolescence through relocation and adaption. More recent work on sustainable retrofitting (Hyde *et al.*, 2012) highlights the opportunities for improving the performance of buildings by replacing elements of the building, for instance the cladding and glazing systems, that have become obsolete with new higher performance elements. For the majority of buildings this process is disruptive. What is perhaps unique about the NSW demountable is that it has been designed to, and demonstrated over 50 years, the ability to facilitate this approach by allowing the building unit to be removed and replaced on its site while the unit requiring adaption is modified in an industrial setting elsewhere: Currently the socially progressive rehabilitation and training programs operated by the NSW Corrective Services industries at Golburn and Cessnock Jails.

To date the NSW demountable program classroom has utilised the opportunity to relocate, re-use and refurbish but appears to have largely ignored the opportunity for adaption. The limited adaptive opportunities that have taken place include the addition of air conditioning from 2003, the addition of lifting points and an improved roof and gutter system.

A review of the original drawings shows that the classroom system was designed to be flexible including such recent innovations as the movable acoustic partition and walls that open to create inside/outside teaching spaces. The substantial steel frame may not have been designed for stacking classrooms on tight urban sites but may well be capable of supporting stacking classrooms with the

addition of an appropriate connection system. The substantial structural frame, previously described as "bomb proof", offers opportunities for fixing other adaptive strategies.

Thermal performance is a more challenging problem. Recent quantitative analysis by the authors (Slee and Hyde, 2015) found that the largest thermal energy input is from the incident solar radiation. The analysis predicted that the internal conditions are, overall, warmer than the external conditions during occupied hours in all NSW climates. Interestingly the analysis also showed that the thermal flux, that is the direction of heat energy transfer, during occupied hours was from inside to outside through the opaque fabric and from outside to inside through the glazing. A review of existing research (Slee *et al.*, 2014a) suggests that developing climate adaptive solutions for the diverse climates of NSW is possible and that a number of researchers have investigated strategies that are applicable. Passive strategies for avoiding external solar gains include the use of ventilated facades (Ciampi *et al.*, 2003) and ventilated roof cavities (Gagliano *et al.*, 2012) which have been shown to reduce cooling requirements by up to 50%. Internal gains from ventilation and activities can be moderated through the appropriate use of thermal mass (Slee *et al.*, 2014b). Phase change materials can be used to provide a relatively lightweight alternative to thermal mass (Memon, 2014). La Roche and Milne (2004) have also shown how a combination of thermal mass, shading and an intelligent ventilation strategy can significantly improve the thermal performance of a space. An interesting study by Cardinale et al (2010) demonstrated how a ventilated roof combined with PCM and a ventilation strategy significantly improved the performance of a lightweight campervan.

10. Conclusion: a radical building

The demountable classroom system was originally designed in 1965 and now, 50 years later, these same buildings are still widely used to achieve the original objectives. They are, however, regarded by many as obsolete. What is remarkable is that while examples of relocatable buildings existed in 1965, most notably from the second world war and its aftermath (Underwood, 1972), the implementation of an industrially produced and adaptable solution was radical and remains radical today. This paper has shown that the NSW demountable classroom system provides the NSW population with an economically, socially and potentially environmentally efficient building system for the State's schools that remains radical. The paper proposes the development of new adaption strategies to improve the thermal performance and flexibility of the building using quantitative and qualitative analysis to inform the design approach and create a high performance building typology that leads building design in the 21st century.

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