Reconsidering Sustainable Building and Design: Lessons from China, Germany and Australia

By

Keri Chiveralls, Jasmine Palmer, George Zillante, Jian Zuo, Lou Wilson and Stephen Pullen
University of South Australia

This paper reports on the initial stages of a research project entitled 'Reconsidering Sustainable Building and Design: A Cultural Change Approach', which is being conducted at the University of South Australia in Adelaide. The project is a three year, Australian Research Council funded endeavour, which seeks to take a whole of life cycle approach to the implementation of ecologically sustainable approaches in building design and construction. The project involves ten partners from government and industry, including partners in Shenzhen University in China and Karlsruhe Institute of Technology in Germany. As such the project is well positioned to take a cross-cultural approach to the analysis of issues associated with the implementation of sustainable building and design practices. This paper reports on the initial phases of the project which included an extensive literature review comparing construction waste management practices in the three study areas: Shenzhen, China; Karlsruhe, Germany; and Adelaide, Australia. The paper begins to explore issues such as the cultural, political, legislative and economic factors which influence the implementation of ecologically sustainable building and design practices, before making some initial recommendations in terms of what can be learnt from the different study regions in order to improve ecologically sustainable outcomes.

Introduction

This paper presents a preliminary literature review undertaken to contribute to the development of the conceptual framework during the initial stages of a three year research project entitled 'Reconsidering Sustainable Building and Design: A Cultural Change Approach'. This paper commences the exploration of such issues through an examination of construction waste management practices in the three study areas of the project: Shenzhen, China; Karlsruhe, Germany; and Adelaide, Australia. The paper argues that there are positive trends in all three study regions which demonstrate a commitment to improving ecological sustainability in the built environment. Substantial changes have been made in the regulatory environments in recent years to minimise waste and improve the recovery of resources from the building and construction waste stream. For example the concept of a circular or closed-loop economy has been strongly promoted in both China and Germany and similar ideas are informing regulatory developments in relation to the management of construction and demolition (C&D) waste in Australia. However, challenges remain and there are clear lessons which can be learnt from an examination of the issues and successes in each study region. This paper is an initial exploration of such issues, which will be examined in greater detail in the research to come over the life of the project.

A Circular Economy for Construction Waste? Lessons from Shenzhen, China

The People's Republic of China has experienced unprecedented growth since the reforms of Deng Xiaoping opened the country to the world market. China's 'socialist market economy' is now the second largest economy and the second largest exporter in the world (Bergsten 2008). As part of these economic reforms, the city of Shenzhen, located in Guangdong Province near Hong Kong, was established as one of the first and most successful of China's Special Economic Zones in 1979. The city has since experienced a rapid pace of development, transforming from a small village to a sub-provincial city with over 10 million residents. As a global superpower, and home to over 1.3 billion people, China has the potential to make a significant contribution to sustainable building, design and construction waste minimisation globally and it is clearly in China's interest to develop strategies to be at the forefront of such issues (Bergsten 2008). China has recently overtaken the US as the world's biggest national polluter and the World Bank estimates that by 2020, China will spend 13 per cent of national GDP or $390 billion annually on the treatment of disease caused by pollution (World Bank 1997; Giddens 2009). The nation's drive for economic growth and its rapid pace of development are often seen to conflict with the agenda for ecological sustainability. For example, then President Hu Jintao announced at a G8 meeting that his country would not accept binding emissions reductions because their per capita emissions were relatively low (by far the lowest of the three nations in this study) and their central task was to develop the economy and create a better life for the Chinese people (Giddens 2009, p.221). It is noteworthy that much of the pollution in China is created by factories that feed the consumption habits of other countries and China still has a relatively low 'ecological footprint' per capita at around 2.21 global hectares per person (compared with the footprints of Germany at 5.09 and Australia at 6.83) (Wackernagel & Rees 1996; WWF 2010).

Despite the President's announcement, the Chinese Government's Climate Change Plan issued in 2006 outlined a commitment to reducing emissions and expanding renewables (Giddens 2009, p.223). The Eleventh Five Year Plan (2006-2011) introduced a number of measures which demonstrated China's pursuit of environmental sustainability, including a 'Green Index' and a commitment to reducing energy consumption by 20 per cent in five years (Lam 2006; Qi et al. 2010). In relation to this plan, Lam (2006, p.10) argued that "In some respects China is ahead of other developed countries, including the US, in creating a national, comprehensive policy for sustainable development." China has signed multiple treaties on the environment including the UN Framework Convention on Climate Change, and the Kyoto Protocol and has implemented the Protocol's Clean Development Mechanism (Lam 2006). In *When a Billion Chinese Jump: Voices from the Frontline of Climate Change*, Watts (2011, p.55) writes "In the nineteenth century, Britain taught the world how to *produce*. In the twentieth century the US taught us how to *consume*. If China is to lead the world in the twenty-first century, it must teach us how to *sustain*." While he later remarks that is it unreasonable to expect China to save the world, he acknowledges that in many ways they are a leading force: "With the government promising enough investment in renewable energy to overtake Europe by 2020, the world's biggest emitter is suddenly being hailed as a budding eco-power." (Watts 2011, p.387) Mao Zedong's policies of overcoming nature (replacing '*tian ren heyi*' or 'harmony between heavens and humankind' with '*ren ding sheng tian*' or 'man must conquer nature') and Deng Xiaoping's ambitious pursuit of growth and encouragement of individualism and materialism did much to suppress environmental consciousness (Lam 2006). However, Watts (2011, p.4) describes how the leadership of hydro-engineer Hu Jintao and geologist Wen Jiabao, or 'President Water and Premier Earth', began to shift the countries rhetoric from red to green, though he remarks that the current reality is more realistically a muted grey.

According to Watts (2011, pp.390-391), the energy use of the average person in Shanghai has surpassed that of London, New York and Tokyo and is 50 per cent higher than the global norm. The Intergovernmental Panel on Climate Change (IPCC 2012) website reports that per capita waste generation in China averages around 1.6kg/day, but that in some rapidly developing cities, per capita waste production is higher than in many developed countries. For example, Shenzhen, per capita waste generation has been estimated at of 2.62 kg/day (IPCC 2012), which is higher than estimates for both the 2005 average for Australia at 2.25 kgs (ABS 2005) and some estimates for Germany of between 1.1 - 1.5 kgs (Gutberlet 2008). With a population of over 1.4 billion, China has the world's largest construction workforce with construction activities comprising 40 per cent of the country's solid waste and over 45 per cent of national energy usage (when operational energy and embodied energy are combined) (Yang, W. & Kohler 2008; Chen et al. 2010; Wang, J et al. 2010; Pullen 2011, p.58; Chileshe et al. 2012). The pace of urbanisation and modernisation is rapid and according to Rees (2009, p.307), China accounts for around 50 per cent of the world's new buildings. Renner (2012, p.14), argues that renovation and retrofitting will be of higher importance in developed countries which have a larger existing building stock and lower population growth rates. However, Yang (2005) found that the Chinese building stock is characterised by a short life span and its rapid modernisation is accompanied by massive demolition of old built assets. According to Qi et al. (2010), every 10,000 square meters of construction produces around 500-600 tonnes of construction waste, while in developed industrialised countries the tonnage for an equivalent area is around 180.

In the last Five Year Plan, the Chinese Government embraced the notion of the 'Circular Economy' and announced that this new development framework would be led at the national level by the National Development and Reform Commission (NDRC) (Ness & Pullen 2006). The NDRC promote the development of a circular economy through a score of legislative, political, technical and financial measures, including policy instruments like government regulations, subsidies and tax breaks (UNEP 2012). The circular economy aims to promote "harmony between the economic system and the ecosystem" by organising economic activity around a closed loop of materials and promoting cleaner production and industrial ecology. (Ness & Pullen 2006, p.3). China's stated approach to a circular economy involves improving resources utilisation and reducing both emissions and waste from the built environment through building adaptation, conversion and renewal (Ness & Pullen 2006). As part of the 12th Five Year Plan, the Chinese government announced an aim to recycle 7 billion tons of industrial solid waste between 2011 and 2015, which amounts to 1.6 billion tons annually and a recycling rate of 50 per cent (Resource Recycling 2010).

The legal situation in China pertaining to C&D waste and sustainable construction is complicated. According to Zhang and Dong (2011), there are four main levels of regulation: laws of sustainable construction implemented nation-wide through state-power; administrative regulations between the national and departmental levels; departmental regulations; and local regulations and department rules. Local regulations and department rules are applicable only if they do not violate the existing laws and regulations. The first three of these are detailed in the tables below.

Table 1: Legislative Framework for C&D Waste in China

Year Introduced	**Laws**	**Function**
1989	*Environmental Protection Law of the People's Republic of China*	Measures for supervision and management of government, environmental protection and improvement from a macro perspective and legal liability
2000	*Law of the People's Republic of China on the Prevention and Control of Atmospheric Pollution*	Measures for supervision and management of atmospheric pollution and related legal liability are mentioned
2003	*Cleaner Production Promotion Law of the People's Republic of China*	Implementation, inducement measures and legal liability of clean production in construction.
2003	*Law of the People's Republic of China on Evaluation of Environmental Effects*	Stipulates evaluation of environmental effects of construction projects
2005	*Law of the People's Republic of China on Prevention of Environmental Pollution Cause by Solid Waste*	Measures for prevention of environmental pollution caused by solid waste in construction projects
2008	*Law of the People's Republic of China on Energy Conservation*	Related measures of rational energy utilisation in construction projects are mentioned
2008	*Law of the People's Republic of China on Prevention and Control of Water Pollution*	Prevention measures and penalties for water pollution in construction projects are mentioned
2009	*The Circular Economy Promotion Law of the People's Republic of China*	Measures of legal liability of decrement and recycling are mentioned
Year Introduced	**Administrative Regulations**	**Function**
1998	*Regulations on the Administration of Construction Project Environmental Protection*	Environmental impact evaluation, methods of environmental protection in construction and legal liability are mentioned
2004	*Regulations on the Administration of Construction Project Production Safety*	Safety liability and legal liabilities of client, designer, supervisor and contractor are included
2008	*Regulations on Energy Conservation of Civil Building*	Methods of energy conservation in civil buildings and legal liability are stipulated
2009	*Regulations on Evaluation of Environmental Effects*	Measures of environmental evaluation and supervision are mentioned
Year Introduced	**Departmental Rules**	**Function**
1987	*Stipulation for Environment Protection Design of Construction Project*	Measures of environmental protection in the design phase of construction projects
2005	*Stipulation for Management of Urban Construction Garbage*	Provisions for disposal of construction garbage such as discharge, transport, backfill and utilisation are mentioned
2005	*Technical Guidelines for Green Building*	Indicator systems and techniques in design, construction and operation of green buildings are included
2006	*Stipulation Energy Conservation Management of Civil Building*	Measures of energy conservation in planning, design, construction and operation
2006	*Measures on Supervision and Management of Conservation Quality in Civil Building*	Liabilities and obligations for energy conservation of client, designer, supervisor and contractor are mentioned
2007	*Green Construction Guidelines*	Outlines the principles and application of green construction guidelines

Source: Adapted from Zhang and Dong (2011, p.797)

Despite the introduction of the spate of legislation outlined above, barriers to the implementation of a circular economy in the construction industry remain. According to UNEP (2012) such barriers include: the lack of knowledge and experience of local officials and citizens on how to move from theory to on-the-ground implementation, insufficient environmental policies, weak planning guidelines, and inadequate coordination between different parts of the authorities and other sectors in society. According to Lam (2006), previous environmental policies were ineffective because they lacked the full backing of the Chinese leadership. Lam (2006) listed obstacles including: institutional weakness of the State Environmental Protection Authority (SEPA); limitations of current environmental law; resistance of local governments; a lack of standards to measure environmental progress; the sheer scale of monitoring over 660 cities; the rarity of prosecution and punishment under SEPA which is only pursued in the most serious of cases; overly broad, overlapping and contradictory laws; weak funding and training; and the resistance of local and provincial governments. As SEPA laws were often seen as obstacles to local growth and development, Lam (2006) reported that a tendency to disregard the laws was frequently tolerated, and the common rivalry among local and provincial governments meant that local officials often chose to cover-up violations rather than report them to central government. As promotion of local officials was often based on their economic growth record, they were often unwilling to follow central government laws, instead pursuing "growth at any cost" (Bergsten 2008, p.78). Similarly, Sha et al (2010), argue that issues arise due to out-dated indicator systems which focus on immediate impact and quantity (as for example through GDP) and ignore issues of quality, efficiency, long-term impact and the environment.

Accordingly, an empirical study investigating construction waste in Shenzhen found most construction materials were dumped in landfills, with the exception of those that were profitable (Wang, Kang & Tam 2008). This finding was supported by an estimate we received of the percentage of C&D waste in Shenzhen which is recycled at around 20 per cent (Li 2012). The study found that construction organisations tended to focus on economic returns and environmental management was rarely considered. Barriers identified included: lack of management skills and supervision; poor workmanship; lack of environmental awareness; lack of training; out-dated construction technologies; lack of law enforcement; low landfilling cost (2-5 yuan per tonne); and high initial cost in implementing recycling technologies (Wang, Kang & Tam 2008). A more recent paper by Wang et al. (2010) found that Chinese contractors prioritised enhancing management capacity in order to construct a better public image, promote competitiveness, and/or reduce costs over improvements in waste management. Similarly, a study by Zhang and Dong (2011), involving 40 interviews with professionals and officials in the construction industry in four cities in China (including Shenzhen), explored issues with the laws and regulations relating to sustainable construction. The main issues identified by respondents included: ‘an incomplete legal system’ (95 per cent) with no specific law on sustainable construction and rules and regulations scattered throughout various other acts and regulations; ‘lack of guidelines’ (90 per cent) on higher-level laws and how they should be applied in practice and in relation to other laws; ‘backward[ness of] some laws and regulations’ (75 per cent), which were formed under very different political and economic circumstances and have not kept pace with the significance of sustainable construction in a socialist market economy; ‘unclear legal liability’ (75 per cent) and a lack of specificity regarding penalties, accountability and criminality of activities; and ‘poor law enforcement’ (65 per cent) with an absence of severe penalties, where penalties for illegal activities are often less than the cost of law-abiding activities. According to Yuan et al. (2011) a significant proportion of C&D waste is also generated through inadequate training and education of construction practitioners and poor construction practices including cutting corners, poor plastering and deformation of materials during transportation and delivery (cited in Chileshe et al. 2012, p.285).

Recommendations to overcome difficulties in the implementation of a ‘Circular Economy’ include: enforcement of legislation; training and education; involving environmental consideration at the design stage; involving environmental consideration in tendering reports; on-site sorting and management systems; increasing landfill levies and improving communication (Wang, Kang & Tam 2008). In the previously mentioned study by Zhang and Dong (2011), respondents suggested: ‘filling the legal gap’ (95 per cent) and ensuring there are appropriate laws for each stage of construction (particularly with regard to planning and design); ‘revising laws and regulations’ (95 per cent) to include specific laws on sustainable construction beginning with the higher level laws and working down; ‘establishing [an] incentive scheme’ (95 per cent) to reward sustainable construction with low-interest finance or tax relief; ‘keeping pace with the level of development’ (95 per cent); and relating provisions in regulations to current circumstances and technologies.

China's experience demonstrates the importance of the effective implementation of regulation and legislation. Some of the issues highlighted above in relation to central-local government relations were flagged during the 2008 National People's Congress, during which SEPA was replaced by the Ministry of Environmental Protection (Bergsten 2008). The central government introduced initiatives which aimed to incentivise its environmental policies through the introduction of a 'Green GDP' Program, which subtracted the cost of environmental damage from net GDP to evaluate the performance of local officials. Unfortunately, this policy was scrapped due to opposition from local officials when GDP in some regions was found to amount to almost zero due to high levels of pollution (ibid, p.83). Other initiatives which were developed included a 'green credit' policy which suspends borrowing rights from polluting companies and a 'green trade' policy which suspends heavy polluters from exporting (Bergsten 2008). Despite arguments that "economic growth and resource consumption and environmental degradation can be decoupled to a considerable extent" (Ness & Pullen 2006, p.2), the lessons from China demonstrate that, real progress towards sustainability in the built environment cannot occur while economic growth, determined through narrow measures, continues to be prioritised above all else.

A Closed-Loop Economy for Construction Waste? Lessons from Karlsruhe, Germany

With a 2008 population of around 82 million people, Germany is the largest country in the European Union (EU) (Yudelson 2009). The City of Karlsruhe, with a more modest population of around 300,000 people, lies in the southwest of Germany, in the state of Baden-Württemberg. Germany is the original home of 'the Greens' and the city of Karlsruhe is where The Green Party (*Die Grunen*) was founded in 1980. Since this time the Party has had a significant influence on German politics and there is substantial agreement among Germany's political parties on the need for action on environmental issues. Germany is a leader in renewable energy and according to Giddens (2009, p.76), is now the world's biggest user of wind power and the largest producer of photovoltaic solar power, with almost 80 per cent of all European solar energy production capacity (Kohler 2003, p.86). However, around half of Germany's power is fired from coal and just under a quarter is supplied by nuclear energy. Germany's New Energy Plan, announced in May 2011, affirmed plans to shut down all 2000 of the country's plants after their 32 year life span and become the first industrialized country to completely shift to clean energy by 2020 (Giddens 2009; World Bank 2012). German understandings of sustainability stem from the term *Nachhaltigkeit*, which derived from a traditional notion originating from shortages experienced in the timber industry in the nineteenth century. Quoting Bachtold (1998), Kohler (2003, p.86) states that the term meant "…'not to cut more wood annually than the forest could give each year', i.e. not to take more than nature could provide." However, Kohler (2003) describes how over time, economic interpretations, which take money as an equivalent for value, became dominant.

Nevertheless, Germany has a reputation for being a leader in environmental policy and waste management, with a history of introducing innovative and controversial policies to create excellent outcomes (Lehmann 2012a, pp.314-316). For example, in 1993 Germany introduced a law requiring that by 2005 all wastes disposed in landfills would have a total organic carbon content of less than 5 per cent, reducing landfill methane emissions by 80 per cent by 2015. The 'Ministry of the Environment, Nature Conservation and Nuclear Safety' is responsible for the development of legislation on C&D waste at the national level in Germany. The Ministry has announced that from 2020 Germany will practically abolish above ground landfill, recovering as much waste as possible (Federal Ministry of the Environment 2006b). However, in order to meet this target, the incineration of waste as an energy fuel has significantly increased, which remains controversial due to issues including toxins released during incineration (Girardet 2003, p.38; Federal Ministry of the Environment 2006a; IPCC 2012).

It is currently estimated that more than 86 per cent of C&D waste is recovered in Germany as the disposal of recyclable C&D materials is forbidden by German law (Federal Ministry of the Environment 2006b; HCEC 2011, p.40; Schultmann & Sunke 2007). In 2004 99.5 per cent was through product/material recovery and 0.5 per cent of this was through combustion with heat recovery. Only a small amount of the remaining waste was treated for disposal, with 25.71 million tonnes of C&D waste being either land-filled (98.8 per cent) or incinerated (0.2 per cent) (Federal Statistical Office of Germany 2006; cited in Schultmann & Sunke 2007).

German waste management legislation is based on EU law, federal law, laws of the regional governments and statutes of local authority waste management services (Federal Ministry of the Environment 2006b). Germany has three main levels of decision-making – the *Bundesrepublik* or federal level, *Leander* or states and *Kommune* or local government level. Due to the historical development of the nation, cities in Germany have greater administrative autonomy and resources than cities in many other European countries (Valentin, Gurtler &

Spangenberg 2000). Since 1974 the European Community has introduced a number of directives that have influenced its member-states in efforts to harmonise their requirements with those of the EU. The European Commission's 1997 Waste Strategy and its Strategy on the Prevention and Recycling of Waste, along with EU-wide regulations and the Waste Framework Directive, have been pivotal (Federal Ministry of the Environment 2006b). The Ministry, supported by the Federal Environmental Agency, oversees the transposition of EU directives and is responsible for the provision of technical instructions regarding waste disposal, including the setting of targets and goals. The *Laender* are also responsible for the implementation of EU and federal government policy, along with the enforcement of regulations to achieve C&D waste goals. Local authorities hold the primary responsibility for ensuring the proper treatment of C&D waste, including the administration and issuing of demolition and construction permits which often incorporate detailed deconstruction plans and recycling specifications for building materials. However, federal legislation ultimately overrides regional and local legislation, should any conflict arise. The regulatory framework for construction waste management in Germany is complex and is only briefly described here. A table showing the main laws and guidelines pertaining to C&D waste in Germany is provided below.

Table 2: Legislative Framework for C&D Waste in Germany

Year Introduced	**Law**	**Function**
1972	First Law on Waste Disposal	Controlled disposal and introduced prevention and separation concepts
1986	Prevention and Disposal of Waste	Introduced waste management principles and recycling
1993	Technical Instructions for Municipal Waste	Specified requirements for treatment, recycling and disposal of waste. Set goals to reduce toxicity and enable recycling
1996	Recycling and Waste Management Act Act for Promoting Closed Substance Cycle Waste Management and Ensuring Environmentally Compatible Waste Disposal	Introduced extended producer responsibility, closed material cycle concept, waste treatment hierarchy (avoid, reduce, reuse, recycle, dispose). Increased powers of enforcement
2003	Commercial Waste Ordinance	Makes separation of wastes from commercial enterprise a legal requirement
2003	Waste Wood Ordinance	Requires the recycling or energetic usage of old wood and prohibits further landfilling
Year Introduced	**Standard/Guideline**	**Function/Issuer**
1997	Environmentally advantageous and low cost treatment of demolition waste	Central Association of the German Construction Industry
1999	Guideline for measurement and recycling planning of buildings to be demolished	German Committee for Reinforced Concrete

2000	Development of methodologies for the assessment of contamination of building materials before deconstruction	German Committee for Reinforced Concrete
2001	Demolition of residential and administrative buildings – guideline 26	Issued by regional office for ecology in Baden-Württemberg
2006	ATV DIN 19459	Set general standards for "demolition and deconstruction work"
2008	Recycling guideline	Federal Ministry of Transport, Buildings and Urban Affairs
2011	Guideline for sustainable construction of public buildings	Federal Ministry of Transport, Buildings and Urban Affairs

Source: Adapted from COWAM (2006, pp.16-17) and CIB (2011)

Much like China's 'circular economy', Germany has a stated aim of developing a 'closed-loop economy', which aims to promote the circulation of resources and the reduction of waste to reduce environmental impacts. In 1994 Germany introduced the Closed Substance Cycle and Waste Management Act, which came into force in 1996. The Act introduced extended producer responsibility (EPR) and aimed to encourage a life cycle economy that avoids waste and encourages producers and consumers to radically rethink their contributions (Federal Ministry of the Environment 2006b). The Act established a hierarchy of 'avoidance, recovery and disposal', and set a primary obligation to avoid waste in production procedures and to promote low-waste products. The Act encourages the development of products that are 'multi-use', 'long-life' and 'repair-friendly', and which can be recycled and disposed of as easily as possible (HCEC 2011, p.40). The Act also implements the 'precautionary principle', the 'polluter pays principle', and the 'principle of co-operation'. These principles are reflected in EPR which requires producers to consider the entire lifecycle of their products and cooperate with suitable agencies to create a strategy which minimises negative environmental impacts and maximises resource recovery (Federal Ministry of the Environment 2006b; HCEC 2011, p.40). The Act encourages construction material manufacturers to redesign products and systems to reduce wastage, facilitate recovery and recyclability after usage, and ensure compatibility with post recovery applications (HCEC 2011, p.40). Building owners, developers, engineers and architects are also considered responsible for integrating a waste management strategy into construction plans, including the use of recyclable building materials (ibid, p.40).

One of the major drivers of success in relation to C&D waste is the *Arbeitsgemeinschaft Kreislaufwirtschaftsträger Bau* or Construction Recycling and Waste Management Industry

Working Group (ARGE KWTB). The group consists of a consortium of construction industry trade associations, who entered into a voluntary commitment with the federal government to achieve a 50 per cent reduction in the amount of landfilled C&D waste in Germany. The industry achieved their ten year voluntary commitment for the fifth time in 2005 with a long term recycling quota of 70.1 per cent and a long term recovery quota of 88.7 per cent (CIB 2011). The German Federal Office for Building and Regional Planning has also developed a Guideline for Sustainable Building to implement integrated principles for sustainable building and design in federal buildings and landholdings (Bunz, Henze & Tiller 2006). The Guideline encourages the use of reusable or recyclable building products and materials, the extension of the lifetime of products and buildings, and a risk-free return of materials to the natural cycle (Bunz, Henze & Tiller 2006).

The lessons from Germany demonstrate the successes that can be achieved through the effective implementation of regulation and legislation to reduce construction and demolition waste. However, despite the high rates of recycling of C&D waste in Germany, there is still room for improvement in the transition to a closed-loop economy. Germany's demand for construction materials far exceeds the amount of recycled building material produced indicating that all recycled building material could potentially be absorbed by the construction industry (COWAM 2006). However, this is not currently occurring due to concerns over performance equivalence with virgin materials (ibid). At present, waste is primarily re-used in a manner which can be characterised as down-cycling, including for backfilling, the erection of noise protection systems and road construction (CIB 2008). However, closed loop recycling, would ideally avoid down-cycling through the re-use of materials for the same purpose or equivalent purpose, maintaining material value (CIB 2002). The proportion of material uptake direct from the construction industry could be improved with more defined information about material characteristics and strict standards for the composition and production of recycled materials (COWAM 2006).

Zero Waste and More Resources? Lessons from Adelaide, Australia

The record of the Australian Government in relation to environmental policy has been quite mixed. For example, despite being one of the biggest per capita energy users and emitters in the world (Garnaut 2008, 2011), the Liberal/National Coalition Government led by Prime Minister John Howard refused to sign the Kyoto Protocol. It was not ratified by Australia until 2008 after the election of the Rudd Labor Government**.** Progress with environmental issues has been hampered by a lack of bi-partisan support, and despite some gains since the Green Party gained balance of power in the Senate, progress remains uncertain, as the opposition is likely to repeal many gains made in this area if elected. Nevertheless, the management of waste has become a pressing environmental concern. The amount of waste produced by Australians has more than doubled over the last 20 years and is likely to double again between 2011 and 2020, as the amount of waste per person grows by 6 to 7 per cent per year (Lehmann & Crocker 2012, p.1). Indeed, Australia is ranked amongst the top ten of OECD nations that generate the highest levels of solid waste (DEH 2001). The Productivity Commission (2006) found that the Australian recycling rate of 35 per cent is much lower than other OECD countries such as Austria (61 per cent) and Germany (56 per cent), and only marginally higher than China with an estimated 25-30 per cent (Australian Government 2006). Methane from the degradable carbon in landfill could represent as much as 85 per cent of Australia's total Greenhouse inventory in 2050.

The Australian Bureau of Statistics (2010) reported that in 2007, a total of 43.8 million tonnes of waste were generated in Australia. The C&D sector accounted for 38 per cent of this and approximately 43 per cent of C&D waste was disposed to landfill. According to the Australian Government (2007, p.29) C&D waste makes up 33 per cent of landfill space in Australia but in many cases this waste can be reduced 80 to 90 per cent through better waste management practices (ibid). The *National Waste Policy: Less Waste, More Resources* (Australian Government 2010), sets the direction for Australia for the next decade and seeks to update and integrate Australia's policy and regulatory framework. The framework includes two strategies relevant to C&D waste: Strategy 10 which aims to "achieve major improvements in waste avoidance and re-use of key materials in the commercial and industrial waste stream", and Strategy 11, which states that all governments are "to continue to encourage best practice waste management and resource recovery for construction and demolition projects." (ibid, p.11) The plan includes milestones relevant to C&D waste as outlined in the table below.

Table 3: Timetable for Relevant Milestones in National Waste Policy

Milestone	**Timeframe**
Current jurisdictional commercial and industrial waste management programs, policies and planning frameworks documented as they relate to encouraging waste minimisation and resource recovery and feasibility of extending/adapting these nationally assessed by 2011	2010 - 2011

Jurisdictions' existing approaches to define when a waste product or material can be readily reused as a beneficial resource identified Existing jurisdictional standards & specifications for recycled C&D & recycled organic waste documented National Stewardship Framework legislation passed *Product Stewardship Act 2011*	
Scope & agree actions to address waste related greenhouse gas emissions Analysis of systemic national impediments to increasing avoidance, reduction, re-use and recycling of commercial & industrial waste completed Waste definitions and classifications documented & mapped to functions Use of jurisdictional approaches nationally for standards & specifications for recycled C&D & organic waste scoped	2011 - 2012
Impediments to C&D waste management & resource recovery documented and best practice examples shared National principles to encourage safe reuse of waste scoped Diagnostics to better match supply & demand of commercial & industrial waste completed Governments commence reporting on sustainable procurement Options for sharing government information on sustainable procurement assessed National principles that guide when a waste product or material can be readily reused as a beneficial resource agreed	2012 - 2013
Impediments to C&D waste management & resource recovery documented and best practice examples shared Sustainable procurement guidance available National principles to encourage safe re-use of waste agreed Benefits & costs of national waste classification options assessed and approach agreed Future work program agreed by 2014	2013 - 2014
Best practice risk assessment of landfill management risks developed Key documents & legislation begin to reference national waste classifications Application of national standards & specifications for recycled C&D & recycled organic waste commences	2015 - 2016

Source: Adapted from (Australian Government 2010, pp.7-8)

In addition to the National Framework, documents like the Australian and New Zealand Government Framework for Sustainable Procurement 2006 also influence approaches to the issue at lower levels of government (HCEC, 2011). However, despite the development of such policies, the Australian Government does not directly legislate management of C&D waste as management of environmental issues is largely considered the responsibility of state and territory governments (Australian Government 2011). The involvement of international treaties or developments deemed to be of significant environmental importance to the nation, are the exceptions to this general rule (ibid). As such the approach of the federal government is one of a multi-stakeholder engagement with multi-party agreements, which may be underpinned by legislative measures where supported by all parties at a jurisdictional level.

Adelaide is the capital city of South Australia (SA), a state which has a reputation for being a leader in progressive policy measures, particularly with regard to recycling and legislation. The use of Extended Producer Responsibility (EPR) approaches, similar to those being applied in Germany (including such measures as Container Deposit Legislation), have ensured SA remain a leader in this regard (CCSA 2009, p.80). According to the Conservation Council SA (2009), in 2006/2007 SA was a leader in the nation with a recycling rate of 68 per cent, recycling 2.43 million tonnes of material, while still sending 1.14 million tonnes to landfill (ibid). This recycling rate was the second highest in the country and SA also had the second lowest level of waste to landfill (ibid). The state has a well-equipped reprocessing industry with 80 per cent of recycling reprocessed locally (with 4 per cent going interstate and 16 per cent exported overseas) (ibid). However, despite such gains the report points out that SA "remains the second-highest generator of waste and is starting to lag behind the other states in tackling issues of over-consumption and resource efficiency." (ibid, p.79)

Zero Waste SA (ZWSA) was established in 2003 as part of the South Australian Government's attempt to tackle such issues. Since this time the recovery rate in SA has improved steadily, with waste to landfill declining 10.4 per cent while the population grew by 3.3 per cent (ibid). However, total waste generation increased over the same period at a faster rate than population growth with total waste generated per person increasing by 4.3 per cent to 2258kg per year (a very high rate of waste generation per capita by national standards, beaten only by Western Australia) (ibid). These worrying statistics reinforce the need for all efforts at improving the sustainability of the built environment to be complemented with a concerted effort directed at broader social change which challenges the dominant paradigm of consumption and growth (Rees 2009). The SA Government aims to divert 90 per cent of waste materials from landfill by 2015 and the passing of the Environmental Protection (Waste to Resources) Policy 2010 will implement landfill bans on certain materials effective from September 2012 (HCEC 2011, p.152).

The main state government legislation of relevance to the management of C&D waste in SA includes South Australia's Waste Strategy 2011–2015, the South Australia Environment Protection (Waste to Resources) Policy 2010, the Environmental Protection Authority South Australia (2010) Waste Guidelines-Waste Levy Regulations, the Hazardous Waste Strategy 2010-2016, he Integrated Waste Strategy for Metropolitan Adelaide 1996-2015, the Zero Waste SA Act 2004, the Environment Protection Act 1993 and the Development Act 1993 (ibid). A number of guidelines also exist addressing the reuse of materials from the waste stream (including the SA Sustainable Procurement Guideline), some of which actively encourage the down-cycling of materials for use as fill (ibid). However, the regulation and legislation of the state and territory governments outlined above only set minimum standards. The creation of new markets through the development and testing of new materials and products, along with other initiatives, are necessary to act as drivers for improvement in the management of C&D waste (ibid).

Of the 1.14 million tonnes of waste still sent to landfill in SA in 2006/2007, 47 per cent of the waste stream by weight was C&D waste, 81 per cent of which was concrete but which also contained other materials including soil/fill, asphalt and bricks (CCSA 2009, p.80). However, the resource recovery rate for this stream was over 76 per cent in 2008 to 2009 (HCEC 2011, p.151). South Australia's Waste Strategy 2011–2015 (Government of South Australia 2011) includes targets to achieve 85 per cent diversion of C&D waste from landfill by 2012 and a 90 per cent diversion by 2015. The market for recycled C&D materials in SA is mature with the road-based industry using around 800,000 tonnes or $20 million worth of product per annum (HCEC 2011, p.146). The city also boasts a significant C&D waste processing industry, which processes resources from residual materials into an engineered fuel which can be burnt in kilns to replace fossil fuels (ibid). This fuel is made predominantly of cellulose based materials and 75,000 tonnes per annum of this processed engineered fuel is utilised locally in the production of cement (ibid, p.151). This significant investment in C&D waste recycling has been encouraged through gradual increases in weight-based landfill disposal levies in SA over time. However, despite this trend there remains a lack of significant differential between landfill gate fees and disposal and the processing costs associated with recovering resources (ibid, p. 146). Furthermore, high volume waste generators continue to receive up to a 30 per cent discount on publicly listed landfill gate fees in the state (ibid).

The SA government runs the Keep South Australia Beautiful (KESAB) Clean Sites Program, in partnership with the state's building industry. The program aims to reduce C&D waste and run-off pollution through on-site training and education programs. The program encourages: audits of the waste stream and education on the sheer volume of waste produced in the industry; stopping the out-dated but previously common practice of stockpiling of materials until the end of the project (which accommodated the transport to and dumping of materials in one-off trips to distant land-fills with lower costs and recycling rates); encouraging the use of skip containers on-site to reduce litter and overall waste; and promotion of the concept ‘a clean site is a safer site’ (ibid, p.147). This program has resulted in a reduction in the volume of waste being generated and requiring disposal in SA as well as improvements in how the waste is disposed of (ibid). The Conservation Council SA (2009) recommended the expansion of this program to include sorting waste prior to landfill.

Despite the positive initiatives described above, an Adelaide study by Zillante & Zuo (2008) assessed the awareness of small construction firms of waste management systems and concluded that there is not enough legislative pressure or incentive to create behaviour change. Concerns remain that the broad range of stakeholders involved in the building and construction process forms a complex supply chain which can produce a barrier to increasing the use of recycled products as “any one link in the chain may potentially veto the use of recycled materials throughout the project.” (HCEC 2011, p.150) Barriers remain to implementing the use of recycled products due to concerns over product quality. For example the Department of Administrative Services (DAIS) tenders state that ‘Recycled Products are not suitable for use in DAIS projects’ (ibid). Concerns over the impact of consumer perception and restrictive legislative standards limiting the potential for recycled materials to compete with virgin materials prompted the formation of Sustainable Aggregates SA, an industry group which aims to provide benchmark standards for products (ibid, p.151). Furthermore, it has been argued that producer responsibility for meeting waste reduction targets in SA is not extensive enough (CCSA 2009).

Nevertheless, in many ways Australia seems to be following Germany’s lead with the effective implementation of legislation to tackle C&D waste. However, the lessons from SA also highlight the importance of looking beyond efficiency issues in relation to sustainable building and design and waste management. Australian engineer William Stanley Jevons is credited with first identifying what is now referred to as the Jevon’s paradox in a discussion relating to the usage of coal (Polimeni et al. 2009, p.5; cited in Lehmann & Crocker 2012). This paradox, also referred to as the ‘rebound effect’ (ibid) or ‘efficiency dilemma’, refers to the observed tendency that an increase in the efficiency of usage of a resource frequently fosters an increased usage of that same resource, rather than creating the desired reductions in resource usage (Brookes 1993; cited in Lehmann 2012b, p.220) Efficiency gains obtained through recycling practices are absorbed if consumption continues to increase at a higher rate, as appears the case with rates of waste generation in SA (CCSA 2009).

Conclusion

This paper represents a preliminary literature review, which was undertaken during the initial stages of a three year project entitled 'Reconsidering Sustainable Building and Design: A Cultural Change Approach'. The paper commenced the exploration of such issues through an examination of construction waste management practices in the three study areas of the project: Adelaide, Australia; Shenzhen, China; and Karlsruhe, Germany. The literature found positive trends in all three study regions with changes to the regulatory environments in recent years to promote the minimisation of waste and improve the recovery of resources from the building and construction waste stream. The concept of a circular or closed-loop economy has been strongly promoted in both China and Germany and similar ideas are informing regulatory developments in relation to the management of C&D waste in Australia. As the experience in China attests, the implementation of the circular economy will face continued challenges as long as it remains embedded in a system that prioritises growth, narrowly measured in GDP, above environmental issues. Though they continue to face challenges with regard to the flow of waste resources back into the industry, both the German and Australian case study demonstrate the gains that can be made through effectively implemented legislation promoting the circulation of resources in the built environment. However, the figures on consumption rates and waste management in SA warn that a focus on recycling and efficient use of resources alone may be insufficient to address the scale of environmental impacts of the industry, especially when coupled with increased rates of growth and consumption. As long as the industry remains embedded in political and economic systems which privilege economic growth driven by consumption and material throughput above all else, there will remain significant barriers to the implementation of truly sustainable building and design. Nevertheless, the quest must not be abandoned as "no industrial sector has greater material leverage and none is better placed to lead the quest for global sustainability." (Rees 2009, p.310)

Acknowledgements

This research has been conducted as part of the Australian Research Council Linkage Project 'Reconsidering Sustainable Building and Design: A Cultural Change Approach'. Many thanks to our project partners including, Professor Frank Schultmann and Anna Kühlen at

Karlsruhe Institute for Technology in Germany and Professor Jiayuan Wang and colleagues at Shenzhen University in China, for their contributions to the research.

References

Australian Bureau of Statistics (ABS) 2005, *Year Book Australia*, ABS, Canberra.

ABS 2010, *Australia's Environment: Issues and Trends*, ABS, Canberra.

Australian Government 2006, *Waste Management: Productivity Commission Inquiry Report*, The Productivity Commission, Canberra.

Australian Government 2007, *ESD Design Guide: Office and Public Buidlings*, Department of Environment, Water, Heritge and the Arts, Canberra.

Australian Government 2010, *National Waste Policy: Less Wate, More Resources - Implementation Plan,* Department of the Environment, Water, Heritage and the Arts, Canberra.

Australian Government 2011, *Construction and Demolition Waste Guide - Recycling and Re-use Across the Supply Chain*, Department of Sustainability, Environment, Water, Population and Communities, Canberra.

Bachtold, HG 1998, 'Nachhaltigkeit, Herkunft und Definitionen eines Komplexen Begriffs', *Schweizer Ingenieur und Architekt,* vol. 116, no. 13, pp. 194-197.

Bergsten, CF 2008, *China's Rise: Challenges and Opportunities*, Peterson Institute for International Economics: Center for Strategic and International Studies; Eurospan [distributor], Washington, D.C. :London.

Brookes, L 1993, 'The Greenhouse Effect: The Fallacies of in the Energy Efficient Solution', *Energy Policy,* vol. 18, no. 2, pp. 199-201.

Bunz, KR, Henze, GP & Tiller, DK 2006, 'Survey of Sustainable Building Design Practices in North America, Europe, and Asia', *Journal of Architectural Engineering*, vol. 12, no. 1, p. 33.

Chen, MZ, Lin, JT, Wu, SP & Luiu, CH 2010, 'Utilization of Recycled Brick Powder as Alternative Filler in Asphalt Mixture', *Construction and Building Materials,* vol. 25, no. 4, pp. 1532-1536.

Chileshe, N, Zuo, J, Pullen, S & Zillante, G 2012, 'Construction Management and a State of Zero Waste', in Lehmann, S & Crocker, R (eds), *Designing for Zero Waste: Consumption, Technologies and the Built Environment*, Earthscan for Routledge, London and New York, pp. 284-306.

CIB 2002, *Design for Deconstruction and Materials Reuse*, Karlsruhe, Germany.

CIB 2008, *Construction Materials Stewardship: The Status Quo in Selected Countries*, Victoria University of Wellington, Wellington, New Zealand.

CIB 2011, *Construction Waste Reduction Around the World,* International Council for Research and Innovation in Building and Construction, Watford, UK.

CCSA (Conservation Council SA) 2009, *South Australia in a Changing Climate: A Blueprint for a Sustainable Future*, Conservation Council SA, Adelaide.

COWAM 2006, *Construction and Demolition Waste Management in Germany*, EU-Asia Pro Eco II B Post-Tsunmami Programme, Hamburg, Germany.

Federal Ministry of the Environment, NaNS 2006a, *Municipal Solid Waste Management Report*, Federal Ministry of the Environment, Nature Conservation and Nuclear Safety, Berlin, Germany.

Federal Ministry of the Environment, NaNS 2006b, *Waste Management in Germany: A Driving Force for Jobs and Innovation*, Federal Ministry of the Environment, NatureConservation and Nuclear Safety, Berlin, Germany.

Federal Statistical Office of Germany 2006, 'Aufkommen, Beseitigung und Verwertung von Abfallen im Jahr 2004', <http://www.bmu.de/files/pdfs/allgemein/application/pdf/abfall_aufkommen2004.pdf)>.

Garnaut, R 2008, *The Garnuat Climate Change Review: Final Report*, Cambridge University Press, Cambridge, <http://www.garnautreview.org.au/CA25734E0016A131/WebObj/GarnautClimateChangeReview-FinalReport30September2008(Fullversion).pdf>.

Garnaut, R (ed.) 2011, *The Garnaut Review 2011: Australia in the Global Response to Climate Change*, Cambridge University Press, Cambridge.

Giddens, A 2009, *The Politics of Climate Change*, Polity, Cambridge; Malden, MA.

Girardet, H 2003, *Creating a Sustainable Adelaide*, Government of South Australia. Thinkers in Residence, Adelaide.

Government of South Australia 2011, *South Australia's Waste Strategy 2011-2015*, Zero Waste SA, Adelaide.

Gutberlet, J 2008, *Recovering Resources - Recycling Citizenship: Urban Poverty Reduction in Latin America*, Ashgate, Burlington, VT.

HCEC (Hyder Consulting, Encycle Consulting & Sustainable Resource Solutions) 2011, *Construction and Demolition Waste Status Report: Management of Construction and Demolition Waste in Australia*, Department of Sustainability, Environment, Water, Population and the Arts and Queensland Department of Environment and Resource Management Canberra.

IPCC 2012, 'Working Group III: Mitigation - Regional Differences', <http://www.ipcc.ch/ipccreports/tar/wg3/index.php?idp=122>.

Kohler, N 2003, 'Cultural Issues for a Sustainable Built Environment', in Cole, R & Lorch, R (eds), *Buildings, Culture and Environment: Informing Local and Global Practices*, Blackwell Pub., Oxford, UK; Malden, MA, pp. 83-108.

Lam, D 2006, 'The Reality of Environmental Sustainability in China', *Policy Matters*, vol. 2, no. 2, Spring, pp. 10-16.

Lehmann, S 2012a, 'The Metabolism of the City: Optimizing Urban Material Flow Through Principles of Zero Waste and Sustainable Consumption', in Lehmann, S & Crocker, R (eds), *Designing for Zero Waste: Consumption, Technologies and the Built Environment*, Earthscan for Routledge, London and New York, pp. 309-342.

Lehmann, S 2012b, 'Sustainable Building Design and Systems Integration: Combining Energy Efficiency with Material Efficiency', in Lehmann, S & Crocker, R (eds), *Designing for Zero Waste: Consumption, Technologies and the Built Environment*, Earthscan for Routledge, London and New York, pp. 209-246.

Lehmann, S & Crocker, R 2012, 'Introduction: People, Policies and Persuasion: The Future of Waste, Reducation and Resource Recovery in Households and Urban Settings', in Lehmann, S & Crocker, R (eds), *Designing for Zero Waste: Consumption, Technologies and the Built Environment*, Earthscan for Routledge, London and New York, pp. 1-8.

Li, J 2012, *Estimate on Percentage of Construction Waste Recycled in Shenzhen*, Shenzhen University, China.

Lu, W, Yuan, H, Li, J, Hao, JJL, Mi, X & Ding, Z 2011, 'An Empirical Investigation of Construction and Demolition Waste Generation Rates in Shenzhen City, South China', *Waste management (New York, N.Y.),* vol. 31, no. 4, pp. 680-687.

Ness, D & Pullen, S 2006, 'Decoupling Resource Consumption from Growth: A New Business Model Towards a Sustainable Urban Environment in China', *Second International Conference on Smart and Sustainable Built Environments (SASBE)*, Shanghai, China, 15th - 17th November.

Polimeni, J, Mayumi, K, Giampietro, M & Alcott, B 2009, *The Myth of Resource Efficiency: The Jevons Paradox*, Earthscan, London.

Pullen, S 2011, 'Circulating Resources, Embodied Energy and Buildings', in Roetman, PEJ & Daniels, CB (eds), *Creating Sustainable Communities in a Changing World*, Crawford House Publishing Australia Pty Ltd, Adelaide.

Qi, GY, Shen, LY, Zeng, SX & Jorge, OJ 2010, 'The Drivers for Contractors’ Green Innovation: An Industry Perspective', *Journal of Cleaner Production,* vol. 18, no. 14, pp. 1358-1365.

Rees, WE 2009, 'The Ecological Crisis and Self-Delusion: Implications for the Building Sector', *Building Research & Information,* vol. 37, no. 3, pp. 300-311.

Renner, M 2012, *Making the Green Econmy Work for Everybody*, Earthscan, London and New York.

Resource Recycling 2010, 'China Going For 50% Recycling Rate', <http://resource-recycling.com/node/2577>.

Schultmann, F & Sunke, N 2007, 'Energy-Orientated Deconstruction and Recovery Planning', *Building Research and Information,* vol. 35, no. 6, pp. 602-615.

Sha, K, Deng, X & Cui, C 2010, 'Sustainable Construction in China: Status Quo and Trends', *Building Research and Information,* vol. 28, no. 1, pp. 59-66.

Sunke, N & Schultmann, F 2008, 'Germany', in Storey, JB (ed), *Construction Materials Stewardship: The Status Quo in Selected Countries*, vol. CIB Report 318, Center for Building Performance Research, Wellington, New Zealand.

UNEP 2012, 'A Circular Economy', <http://www.unep.fr/scp/nap/circular/about.htm>.

Valentin, A, Gurtler, M & Spangenberg, JH 2000, 'Sustainability and Urban Policy in Germany: Retrospect and Prospect', in Low, Net al (eds), *Consuming Cities: The Urban Environment in the Global Economy After the Rio Declaration*, Routledge, London and New York, pp. 110-130.

Wackernagel, M & Rees, WE 1996, *Our Ecological Footprint: Reducing Human Impact on the Earth*, New Society, Philadelphia, Pa.

Wang, J-y, Kang, X-p & Tam, VWY 2008, 'An Investigation of Construction Wastes: An Empirical Study in Shenzhen', *Journal of Engineering, Design and Technology*, vol. 6, no. 33, pp. 227-236.

Wang, J, Yuan, H, Kang, X & Lu, W 2010, 'Critical Success Factors for On-Site Sorting of Construction Waste: A China Study', *Resources, Conservation and Recycling*, vol. 54, no. 11, pp. 931-936.

Wang, JY, Yauan, HP, Kang, XP & Lu, WS 2010, 'Critical Success Factors for On-Site Sorting of Waste: A China Study', *Resources, Conservation and Recycling*, vol. 54, no. 11, pp. 931-936.

Watts, J 2011, *When a Billion Chinese Jump*, Faber and Faber, London.

World Bank 1997, *Clear Water, Blue Skies: China's Environment in the New Century*, The World Bank, Washington, DC.

World Bank 2012, *China 2030: Building a Modern, Harmonious, and Creative High-Income Society*, The World Bank, Washington, DC & Development Research Center of the State Council, The People's Republic of China.

WWF 2010, 'Living Planet Report 2010: Biodiversity, Biocapacity and Development', <http://wwf.panda.org/about_our_earth/all_publications/living_planet_report/demands_on_our_planet/>.

Yang, W 2005, 'Simulation and Evolution of the Chinese Building Stock', *The 2005 World Sustainable Building Conference*, Tokyo, Japan, 27th-29th September.

Yang, W & Kohler, N 2008, 'Simulation of the Evolution of Chinese Building and Infrastructure Stock', *Building Research and Information*, vol. 36, no. 1, pp. 1-19.

Yuan, H, Shen, L & Wang, J 2011, 'Major Obstacles to Improving the Performance of Waste Management in China's Construction Industry', *Facilities*, vol. 29, no. 5/6, pp. 224-242.

Yudelson, J 2009, *Green Building Trends: Europe*, Island Press, Washington, DC.

Zhang, W & Dong, J 2011, 'Research on Laws and Regulations of Sustainable Construction in China', *World Academy of Science Engineering and Technology*, vol. 78, pp. 796-800.