

A Systemic Review of Sustainability Research in the Quarrying Industry

Abstract

To be a sustainable industry quarrying faces many challenges in the next 50 years including leadership, sourcing new resources, accessing human resources, new training needs, research, relationship with suppliers, customers, product users, product sales, product use, safety, access to finance, product quality, operational changes and environmental management including planning and delivery.

This paper outlines the current research in these key areas and the opportunities for future research.

1.0 Introduction

In 1987 Our Common Future (Bruntland 1990) was released to address sustainable development and how this could be achieved. One of the key concepts of the report was the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs (Bruntland 1990).

Since then there has been a number of sustainability guidelines established by International Agencies, Industry Sectors and Government Agencies.

Perhaps the most recognised guideline is the Global Report Initiative (GRI). GRI's vision is to have transparent reporting on economic, environmental, social and corporate governance issues. They have also developed sector supplements for the following industries

- Airport Operators
- Construction and Real Estate
- Electric Utilities
- Event Organisers
- Financial Services
- Food Processing
- Mining and Metals
- Oil and Gas
- Public Agency
- NGO - Non Government Organisations

and in development

- Apparel and Footwear Sector
- Automotive

- Media
- Telecommunications

The GRI Guidelines include standard disclosure for profile strategy and analysis, organisation profile, report parameters and governance commitments and engagement. It has performance indicators for environment, human rights, labour practices and decent work, society, product responsibility and economics.

Other international sustainability initiatives include

- United Nations Global Compact, which considers the following issues of human rights, labour, environment, anti –corruption, business and peace, financial markets, business for development, UN Business Partnerships and supply chain sustainability.
- International Sustainability Indicators Network
- Other Industry initiatives are summarised in table 1

Industry	International	Guide / Framework and Link	Australia	Guide / Framework and Link
Cement	World Business Council for Sustainable Development Cement Sustainability Initiative	http://www.wbcscement.org/index.php?option=com_content&task=view&id=174&Itemid=232	Cement concrete & aggregates Australia	http://www.concrete.net.au/#
Engineering	Engineers for a Sustainable World	http://www.eswusa.org/	Engineers Australia	http://www.engineersaustralia.org.au/colleges/environmental/activities/sustainability/sustainability_home.cfm
Finance, investment	Dow Jones Sustainability Index	http://www.sustainability-index.com/		
Mining	International Council of Mining and Meteorology	Sustainable Development Framework http://www.icmm.com/our-work/sustainable-development-framework	Minerals Council of Australia Enduring Value	http://www.minerals.org.au/focus/sustainable_development
Property	International Sustainability Alliance	ISA 2011 Benchmarking Reporting http://www.internationalsustainabilityalliance.org/	Green Building Council Five star buildings	http://www.gbca.org.au/
Travel	Green Global	http://www.greenglobe.org/ http://www.sustainabletravelinternational.org/	Tourism Australia	Sustainability toolkit and resources http://www.tourism.australia.com/en-au/industry/sustainable-tourism_5583.aspx
University	University	http://www.ulsf.org/res	ACTS	Resources (members only)

	leaders for a sustainable future)	ources_campus_sites.htm	Australasian Campuses Towards Sustainability	http://www.acts.asn.au/index.php/resources/
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Table 1: Examples of industry with recognised sustainability initiatives

1.1 Sustainability Defined

Sustainability is given numerous definitions in the literature, however, the most recognised is The Bruntland Commission’s definition of sustainable development, “development that meets the needs of the present without compromising the ability of future generations to meet their own needs.” (Bruntland 1990).

1.2 Benefits of a Commitment to Sustainability to Business

Sustainability is a pressing contemporary challenge that demands innovative approaches. In 2009 The Business of Sustainability report was released. It found that the benefits of addressing sustainability in a business included (in order of benefits)

1. Improved company or brand image
2. Cost savings
3. Competitive advantage
4. Employee satisfaction, morale or retention
5. Product service or market innovation
6. Business model or process innovation
7. New sources of revenue or cash flow
8. Effective risk management
9. Enhanced stakeholder relations (Berns et al 2009)

Sustainability is a pressing contemporary challenge that demands innovative approaches. (Berns et al 2009)

1.3 The Role of Industry Association in the Promotion of Sustainability

A 2007 Canadian study (Brady et al 2007) on the role of industry associations in developing a position on sustainability, found that it required board commitment and dedicated staff with responsibility to implement the strategy.

Industry groups were focused on:

1. Communities (5/7)
2. Employees (5/7)

3. Customers (1/7)
4. Shareholders (0/7)
5. Suppliers (2/7)
6. Governance & ethics (2/7)
7. Environment (7/7)
8. Formal, ongoing stakeholder engagement programs (2/7)
9. Measuring, monitoring, verification and reporting and communications (3/7)
10. Indigenous communities (3/7)
11. Human rights (0/7)
12. Security (0/7)
13. Public policy / government relations regarding sustainability (7/7)

The report also outlined the reported benefits by members of being involved in an industry association sustainability program. These are consistent with advantages (Berg et al 2009) above and include

1. Platform for involvement
2. Improves practice and performance
3. Cost effectiveness
4. Competitive advantage opportunities
5. Improves risk management
6. Improves stakeholder / government relationships
7. Improves market access
8. Forestalls government regulation
9. Improves morale and productivity

The Australian quarrying industry currently has no formal position on sustainability. This purpose of this paper is to consider if it is necessary to have a formal position in order to provide value to the industry and if a framework will provide a structure for developing a system to identify current performance, measure and implement strategies to improve and garnish the advantages reported in other sectors.

The industry communicates its current issues on sustainability through industry publications and industry conferences.

The objective of this paper is to evaluate the peer reviewed articles in the literature associated with quarrying and sustainability, published since 1987, specifically in the areas economic, environmental and social development, in order to determine future directions in research . The GRI is used as framework for this review and the GRI approach is utilised to consider governance performance, economic, environmental and social impacts.

1.4 Limitations of the Study

Readers should be aware of the following study limitations that influence the findings:

- The definition of sustainability for the purpose of the study – We used whatever term was adopted by the author to define its activities.
- Limited sample size – As less than 40 papers were included in the study, one should be cautioned on drawing broad conclusions.
- The Study did not analyse the sustainability outcomes – The purpose of the study was to consider the areas which require further research in the quarrying industry in relation to sustainability.
- The initial scope of the paper was to consider only Australian research, however, not enough papers fitted the search criteria and the scope was expanded to all international papers written in English.

2.0 Methodology

A systematic search of the literature was conducted to identify research since 1987 which related to sustainability in the quarry industry. Studies were included if they met the following criteria:

1. related to quarrying
2. related to sustainability
3. published in 1987 or later (post Bruntland 1987)

The search for relevant literature utilised the following:

1. Search providers and databases: Google scholar, Google, PsycInfor database, **Science Direct, Elsevier Science, Emerald, Pergamon**, Academic Search Premier, Masterfile Premier.
2. The following key words for computer based searches: Quarry, sustainability, leadership, product life cycle, risk, environment, rehabilitation, water, safety, communities, employees, customers, shareholders, suppliers, governance, ethics, environment, communications, indigenous human rights and security.
3. A direct web search was done for sustainability advantages and industry associations.

4. The following websites:

- www.gri.org
- www.icmm.org
- www.minerals.org.au
- www.quarry.com.au

3.0 Results

Authors and Year	Country	Area of Sustainability	Sustainability Factors	Types of Paper	Management of Sustainability	Summary of Paper
1. Governance, Commitment and Engagement						
Miller 2003	Australia	Corporate governance leadership, teamwork and quality	Social/economic Employee engagement and quality outcomes	Case Study	Creating defined work groups for teams	Teamwork improved productivity, quality and employee empowerment
Harris 2007	Australia	Corporate engagement	Role of leadership, structure, resources, culture and understanding for engaging in sustainability	Case Study	Corporate engagement	Internal co-operation factors that influence sustainability
Evans et al 2009	United Kingdom	Land use	Land reuse	Case Study	Need to utilise vacant space and address public policy	Evaluate land use of occupancy, underground storage and social and planning issues
2. Economic						
Rehman & Ali Asad 2009	Pakistan	Economic	Programme and scheduling	Random	Strategy to optimize inputs to products to limit hold-ups in delivering to customers	Review short range production schedule though cost minimisation
Brown et al 2011	UK	Economic	Access to land use planning	Opinion	Supply of aggregates are more economically and environmentally advantageous when sourced locally	Considers the environmental cost and economic benefits of aggregate

3. Environmental						
Twardock & Hermann 1998	USA	Environment	Land reuse	Case Study	Abandoned quarry as landfill	Outlines site specific challenges and advantages of change in land use
Mercer & Marden 2005	Australia	Environment	Government Policy	Opinion	Public policy does not prevent species decline	Critical of political party policies to protect ecological biodiversity especially in regards to extractive and primary industry
Cullen et al 1997	UK	Environment	Rehabilitation, rabbit grazing risks	Case Study	Use of blasting	Compares rehabilitation techniques to the restoration of vegetation to full vegetation
Bonali & Dall'Ara 2011	Italy	Environment	Rehabilitation, using paper industry waste	Case Study	Use of paper sludge	Evaluates paper slurry for rehabilitation to secure site safely and reduce methane production
Mayes et al 2005	UK	Environment	Discharged water quality and impact on downstream wetland vegetation	Case Study	Dewatering water with high pH and sediment laden impacts vegetations	Water quality discharged off site created nutrient poor calcareous substrate that reduced colonisation of flora
Segarra et al 2010	Spain	Environment	Blasting – over pressure	Case Study	Predict air blast	Model used to assess the range of maximum blast overpressure for a particular blast design
Oliveia et al 2011	Portugal	Environment	Rehabilitation	Case Study	Substrate treatments	Evaluates substrate treatment and the survival and regrowth of vegetation

Rockliff 1996	UK	Environment	Waste product use	Case Study	Development of European standards for aggregates and road materials	Argues for new European standards for using unbound mixtures
Almendro-Candel et al 2006	Spain	Environment	Sewage sludge during reclamation	Case Study	Utilise sewage sludge to degraded soils in rehabilitation	Evaluates leachates from sewerage sludge
Mouflis et al 2008	Greece	Environment	Visual impact	Case Study	Provides a model to assess visibility loads	Identifies changes to landscape and ecological impact
Neri & Snachez 2010	Brazil	Environment	Rehabilitation	Observation	Concludes leadership and environmental qualifications are essential for best practice outcomes	Evaluates best practice rehabilitation methods and their application
Mitchell et al 2003	UK	Environment	Reuse of mineral waste	Observation	Use mineral waste	Reuse of mineral waste is being driven by economics
Wang et al 2011	China	Environment	Rehabilitation	Observation	Restoration of abandoned quarry improves ecological value	Restoration is assisted by increasing economic income
Raman et al 2011	Malaysia	Environment	Waste management	Observation	Use waste products quarry dust and rice husk ash	Research indicates that even though quarry dust inclusion as partial replacement of sand results in some minor negative impacts to the workability of fresh concrete, it can be compensated by a good mix design and by the use of superplasticizer

Duan et al 2007	China	Environment	Restoration	Observation	Natural recovery and the use of sludge and introduction of species to add in recovery	Spontaneous succession in the quarry was at different rates for the terrace, spoiled mound and side slope
Duval et al 2010	Canada	Environment	Wetlands – calcareous fens	Case Study	Compares substrate treatment for restoring vegetation in a wetland	Effectively transplanted a species in an abandoned quarry
Dong-dong & Li Le 2009	China	Environment	Restoration	Observation	Abandoned quarries should be used for ecological, cultural and leisure	Applying principle of ecological landscape design
Adhikari et al 1990	India	Environment	Air quality	Case Study	Blast design and reduced charge minimise fines Geological feature may play a factor in fine reduction	Provides blasting recommendations for a limestone quarry
Duque et al 1998	Spain	Environment	Rehabilitation	Case study	Applying Geomorphological criteria to restoration Provide long term restoration plans	In areas with limited budget stabilising earth movements will enhance ecological recovery
Phillips 2011	Israel	Environmental	Measure of sustainability using a nominated model	Observation	Un-rehabilitated quarries have the potential to create	Past and current cluster of quarry need to be examined, nominates a model to evaluate
4. Product Responsibility						

Traverso Et al 2010	Italy	Product Lifecycle	Embodied energy of marble	Case Study	Environmental considerations include spoil produced during extraction, disposal of sludge from processing marble and water recycling and energy consumption of the quarry	Management of natural resources in product lifecycle needs to be considered
Karvinen & Bennett 2006	Singapore	Role of Customer	Customer	Observation	Improves product quality	Improving productivity, quality and service
Achtemichuck et al 2009	Canada	Use of Waste Products	Use of waste products	Observation/random	Use of quarry dust and waste ash incineration	Provides controlled low strength material CLSM for slag and fly ash without using Portland cement
Akbulut & Gurer 2006	Turkey	Use of Waste Products	Use of waste products	Random	Use of marble quarry waste as aggregate	Light and medium trafficable asphalt pavements can use marble quarry waste as aggregate
Rupnow et al 2010	USA	Use of waste products	Use of waste product	Observation	Use of waste products in roadway construction	Evaluates the effectiveness of stabilised limestone screening in road construction
Touahamia 2002	UK	Product	Use of recycled products	Observation	a) economical efficiency of using recycled materials in place of natural materials and (b) evaluation of engineering parameters which are essential for safe and economical design, practical information is required for designers	Recycled materials yielded significantly lower shear strength when compared with the crushed rock. The results also showed a significant reduction in shear strength when the materials were smeared with clay slurry. The use of soil reinforcement resulted in a significant increase in the shearing resistance of the granular materials, in some cases an increase of up to 50%
5. Labour Practices						

Dhillon 2009	Canada	Safety	Equipment safety	Observation	Electrical safety, human factors	Identified cause of accidents and makes recommendations for equipment improvements
Ulm et al 2004	Germany	Safety	Air quality and worker health	Random	Reduce exposure level to a peak exposure below 0.15mg/m ³ and an average exposure 0.10mg/m ³	440 workers compensated for silicosis reviewed in order to consider job and exposure
Hartikainen & Tossavainen 1997	Finland	Safety	Air quality and worker health	Random	N/A	Scanning
Alejano et al 2007	Spain	Safety	Prevent rock falls	Random	Rock slope stability design rockfall safe slopes	Applies road engineering and adapts for application in quarry
Alejano et al 2008	Spain	Safety Risk	Safety – rock falls	Case Study	Manage rock fall risk	Uses a method to predict risk of rock falls
Kodamo et al 2008	Japan	Safety	Use of a model to predict rock slope deformation	Case Study	Rock slope stability	Use of a model to predict rock slope deformation and determine the operations could continue
Millar & Salt 2008	UK	Social Resources (accessing employees)	Social Human resources	Observation	Mobility of skills required to service industry	Mobility of staff plays different roles in different companies, how to get the most out or redeployment, cost was not a consideration in deployment
6. Human Rights						
7. Society						

In total the search identified 109 articles of which 40 met the above the criteria. These are divided into the following areas

1. Governance, Commitment and Engagement
2. Economic
3. Environmental
4. Product Responsibility
5. Labour Practices
6. Human Rights
7. Society

The papers are summarised in table 2. The papers represented a wide geographic spread with one paper coming from each of the following countries Singapore, Germany, Finland, Malaysia, Israel, Turkey, Pakistan, Japan, Portugal, Greece, Brazil and India. Two papers were based on research in Italy. There were three papers from Australia, the USA, Canada and China. Research in Spain resulted in 5 papers and the most research is focused in the UK.

The research identified a limited number of journals, which met the criteria. In order to determine if the research was extensive and covered a cross section of relevant topics for analysis, the number of potential journal articles were identified using a key word search for quarry, mining, extractive industries and construction. The results are summarised in table 2 and indicate an under representation of the quarrying industry in academic research.

Key Word Search Journals Only Science Direct	Number of Journal Articles (since 2001)
Quarry	25,344
Extractive Industry	10,461
Mining	251,626
Construction	976,199
Sustainability	66,798
Quarry & sustainability	30
Extractive Industry & sustainability	62
Mining & sustainability	410
Construction & sustainability	1,168

Table 3: Industry and Journal Based Articles

3.1 Governance, Commitment and Engagement

The GRI indicates corporate governance as a key area in addressing sustainability. The GRI guidelines include governance, commitment to external initiatives and stakeholder engagement. The author included leadership as the most appropriate place to consider this key area. Three papers that met the above criteria were reviewed.

3.2 Economic

The GRI indicates economic performance as a key area in addressing sustainability and include economic performance, market presence and indirect economic impacts. Two papers met this criteria.

3.3 Environmental

The GRI indicates environmental performance as a key area in addressing sustainability and include material use, energy use, use of water, impact on biodiversity, emission , effluents and waste, products and services, compliance and transport . The majority of papers were based on environmental issues with 20 papers meeting the above criteria. Most of these papers considered rehabilitation of quarries.

3.4 Product Responsibility

The GRI indicates product responsibility as a key area in addressing sustainability and include customer health and safety, product and service labelling, marketing communications and customer privacy. Six papers met the above criteria with the majority of those addressing product lifecycle and recycling waste for reuse.

3.5 Labour Practices

The GRI indicates labour practices as a key area in addressing sustainability and include employment, labour management relations, occupational health and safety, training and education, diversity and equal opportunity and equal remuneration for women and men.

Seven papers met the above criteria and the majority of these were based on safety with particular reference to respiratory health and rock slope stability.

3.6 Human Rights

The GRI indicates human rights as a key area in addressing sustainability and includes local investment and procurement practices, non-discrimination, freedom of association and collective bargaining, child labour and forced and compulsory labour, security practices, indigenous rights, assessment and remediation. No papers met the above criteria.

3.7 Society

The GRI indicates society as a key area in addressing sustainability and includes local community, corruption, public policy, anti-competitive behaviour and compliance. No papers met the above criteria.

4.0 Discussions

It appears that the quarrying industry may be under represented amongst the academic literate. In general there is very limited research on how the quarrying industry rates in its commitment and implementation of sustainability.

Within the limited literature reviewed there is a shortage of experimental validated studies on which to draw firm conclusions. Most of the papers reviewed looked at their subject matter in isolation without a link to broad policy objectives.

The papers did not relate to the current issues in the quarrying industry as outlined in the industry publications and papers presented at industry conferences.

One of the limitations of the research is there is no one definition for sustainability, quarry, quarrying or extractive industries.

Many papers were based on one site without an opportunity to compare and test hypothesis.

Current strengths

Based on the limited literature available, the following is covered by research

- Environment, in particular, rehabilitation
- Product , lifecycle and waste use

Opportunities

There are opportunities for further research on how quarrying can identify, measure and improve its performance in the following areas

- Governance, Commitment, Leadership and Engagement
- Economic
- Labour Practices
- Human Rights
- Society

The author speculates that the review poses more questions than we have evidence to answer and suggests the industry consider these questions?

1. Does the Australian Quarry Industry need a formal position on sustainability?
2. If the industry chooses to adopt a formal position on sustainability what model would be adopted
 - environmental sustainability
 - triple bottom line (environmental, economic, social)
 - triple bottom line plus One (corporate governance)
 - GRI

- Other by consultation
3. Would the adoption of a sustainability model require signatories from member and non member companies , and would this be from the Managing Director
 4. What would the priority areas for implement a sustainability model and what would be the indicators
 5. Given the research into environmental performance of quarries, is there a case for self regulation , how can we utilise this information for public policy reform what does the industry need in order to self regulate
 6. Have we done everything we can to address safety? No one is injured; no one' s health is affected by work in quarries?
 7. Are the industries labour practices above the national standard or below? Do we have equal representation of men and women in all areas of our operations?
 8. If we ignore labour practices will they go away?
 9. Human rights? Can we just assume we have it right?
 10. Society? Ditto
 11. Given what we know about product life cycle responsibility and at all stages of the product, waste and the recovery of used products how do we maximise the value of the commodity. Is the pricing strategy of quarried products consistent with the life cycle?
 12. If companies retained ownership of a product what is possible? How would the industry restructure? Should the industry stop selling product ? Can it be leased?
 13. What role can social media play to shape the Quarrying industry future, Or will it be shaped by social media? What is the role of social media in implementing, monitoring performance of the industries performance in sustainability?

6.0 Where to From Here

1. Adopt a strategy for research and improving quarrying representation in academic research for key areas based on influencing public policy
2. Build on research in other areas, e.g., mining, construction, environment, etc.
3. Rewrite this paper with anecdotal evidence from industry sources to identify trends
4. Consult with industry on the desire for sustainability guidelines
5. Identify what issues require a collaborative effort and fund collaborative research in order to address
6. Consider developing an industry position on sustainability
7. Provide research resources for industry use
8. Fund research

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