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Barriers to implementing reverse logistics in South Australian construction organisations

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Abstract
Purpose – This paper aims to present a survey of the perceptions of the barriers to implementing reverse logistics (RL) practices in South Australian (SA) construction organisations. Despite the extensive research on forward logistics and RL, there is a paucity of studies that examine the barriers to implementing RL particularly within the Australian construction industry. This study builds on the ongoing research being undertaken by the authors, entitled "Designing for reverse logistics (DfRL) within the building life cycle: practices, drivers and barriers", which is examining the best practices and drivers that could be used as a "road map" for developing appropriate solutions for the successful implementation of RL.
Design/methodology/approach – Data were collected by utilising a triangulated data collection approach, a literature review and 49 questionnaires. The review of the literature identified 16 barriers to implementing RL. The quantitative survey data were subjected to descriptive and inferential statistics with correlation analysis to examine the relationships between different pairs of variables comprising RL's critical barriers.
Findings – The following barriers were indicated as most significant: lack of incorporation of salvaged materials by designers; regulation restrictions to usage of recovered materials and components; potential legal liabilities; higher costs; and longer-time association with deconstructing buildings. The least ranked barriers were mostly drawn from the operational and industrial categories as being: organisational lack of support for deconstruction due to incompatible design; lack of organisational support for deconstructing buildings due to higher health and safety risks; and inadequate skills and experience for deconstruction (operational). The industrial barrier was related to "higher costs of salvaged materials in comparison to virgin products".
Research limitations/implications – First, the reported findings are focussed on one study that used questionnaire surveys within the construction industry; therefore, the results may not be generalisable to other contexts. Further, studies should be conducted and extended to other industrial sectors beyond the construction industry. Second, the quantitative study ($n = 49$) used a smaller sample, and the survey items were based on the review of the literature.
Practical implications – The identified barriers could be used as a "road map" for the development of appropriate solutions for the successful implementation of RL, and to improve the environment-related decision-making processes of contractors.
Originality/value – This study makes a contribution to the body of knowledge on the subject of RL within a previously unexplored SA context. In addition, the study provides some insights on the contributory effects of the barriers to the implementation of RL. It is the first work undertaken to determine the barriers to the adoption of RL within the SA construction industry.

Keywords Construction industry, Barriers, Reverse logistics, South Australia, Correlation analysis & Descriptive statistics, Supply chain management, SCM

Paper type Research paper

1. Introduction

This study builds on the ongoing research undertaken by the authors, entitled "Designing for reverse logistics (DfRL) within the building life cycle: practices, drivers and barriers"; which is exploring and identifying the best practices and drivers that could be used as a "road map" for the development of appropriate solutions for the successful implementation of reverse logistics (RL). The South Australian (SA) construction industry plays a critical role within the public and private sectors of the national economy. According to the Australian Bureau of Statistics (ABS) (2013), the industry accounts for approximately 7 per cent of Australia's gross domestic product, and employs more than 60,000 people, thereby making it the seventh largest employer

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This paper provides the background to the successful Zero Waste SA Sustainable Design and Behaviour (sd+b) Centre's Research Funding Scheme's 2013 program: "Designing for reverse logistics (DfRL) within the building life cycle: practices, drivers and barriers". The project team comprises Dr Nicholas Chileshe, Prof Steffen Lehmann, Dr Raufdeen Rameezdeen and Mr M Reza Hosseini. The authors would like to express their sincere gratitude to two anonymous reviewers and the editor of *Supply Chain Management: an International Journal* for their constructive and helpful comments which have enhanced the quality of earlier versions of this paper.

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in South Australia (Chileshe *et al.*, 2012, p. 284). Despite the recent contraction within the SA construction industry, according to the Australian Construction Industry Forum (2014), the state's engineering construction industry still has plenty of work. While the importance of the SA construction industry is acknowledged in Australia at federal and state levels, it continues to generate a large amount of waste (Chileshe *et al.*, 2012). In addition, as noted by Zero Waste (2011), it faces a number of challenges in waste management, particularly those arising from municipal solid waste; commercial and industrial waste (C&I); and construction and demolition waste (C&D).

This problem of waste generation is not unique to South Australia, and Australia as a whole, but also globally. For example, from the Latin American perspective, Nunes *et al.* (2009) observe that the majority of C&D is not recycled. Similarly, in China, the world's largest developing country, several studies such as the work of Wang *et al.* (2010) and Chen *et al.* (2010) provide evidence that the Chinese construction industry generates 300 million tonnes of waste annually. According to the studies cited, this is equivalent to 40 per cent of the total amount of China's waste. Evidence from studies in other parts of the world such as South Africa (Shakantu *et al.*, 2008; Shakantu and Emuze, 2012), Europe (Barros *et al.*, 1998) and India (Jindal and Sangwan, 2011) has reported that the construction industry contributes to a large share of the consumption of the world's resources and that a large amount of waste is generated in construction activities. This situation has further illuminated the need and renewed calls to explore the application of concepts such as RL to help address some of the challenges and problems associated with waste generation (Pokharel and Mutha, 2009; Razaz, 2010; Schultmann and Sunke, 2007a; Aidonis *et al.*, 2008; Kibert, 2012; Addis, 2006b). The highlighted studies have identified RL as a mechanism for easing the detrimental environmental effects of the construction industry. For example, Pokharel and Mutha (2009) acknowledge that the focus of RL is on waste management, materials recovery (recycling), parts recovery or product recovery (through remanufacturing).

The study and implementation of RL have been closely aligned with the improvement of profits and costs minimisation (Sachan and Datta, 2005; Chiou *et al.*, 2012; Ho *et al.*, 2012) and with value creation (Chiou *et al.*, 2012). For example, Chiou *et al.* (2012) note that RL has become important, not only as a source of opportunity for companies to improve their visibility and profitability and achieve lower costs across the supply chain, but also as a strategic activity because it can create value (Chiou *et al.*, 2012, p. 275). Some construction-specific studies in RL have highlighted the improved exchange of information and coordination between involved parties during the design and construction stages (Shakantu and Emuze, 2012). Similarly, the reverse flow has been found to:

- considerably improve global performance (Turrisi *et al.*, 2013) and economic and strategic benefits (Autry, 2005);
- to increase revenue, thus gaining market share (Daugherty *et al.*, 2002);
- to act as a market differentiator and profit centre (Stock, 2001; Stock *et al.*, 2002); and
- to improve innovation and a firm's performance (Richey *et al.*, 2005b).

Carter and Ellram (1998, cited in Ashby *et al.*, 2012) have highlighted that the goal of RL is resource reduction through recycling, reuse and waste elimination. Despite the noted benefits associated with RL, only limited studies have focussed on RL within the context of Australia. A number of authors have added their support to the growing consensus that RL is not yet commonplace, not only in the construction sector (Schultmann and Sunke, 2007b; Kibert, 2012; Leigh and Patterson, 2006; Durmisevic and Yeang, 2009), but also in the largest developing countries such as China (Abdulrahman *et al.*, 2014) and India (Jindal and Sangwan, 2011). Tibben-Lembke (2002) has attributed the limited number of studies in RL to the relative newness of this area of research.

Despite the SA construction industry being one of the contributors to the generation of waste, anecdotal evidence suggests that the industry has been slow in embracing effective environment-friendly practices such as RL and waste management. While it is acknowledged that RL is still in its infancy in the majority of developing countries, even from the perspective of the Australian federal and state level in what is regarded as a developed country, there is a lack of empirical studies on RL. As this is an under-researched and previously ignored area, examination of the critical barriers and gaining an understanding of the reasons behind the low level of adoption of RL by the SA construction industry is urgent and relevant. To fill this knowledge gap, the current study used a triangulated data collection approach to examine the critical barriers in implementing RL. Sandberg and Alvesson (2011) identified three basic gap-spotting modes which assist researchers in constructing research questions as follows:

RQ1. confusion spotting;

RQ2. neglect spotting; and

RQ3. application spotting.

The associated specific version of the neglect spotting mode applicable within this particular area of RL research would be due to this being an overlooked area, an under-researched area or an area lacking empirical support. It is expected that the outcome of the study will inform various stakeholders of the most critical barriers with which they should be working (rather than thinly spreading their resources to popularise RL within the construction industry) and to make a contribution to the development of appropriate strategies and solutions for overcoming the identified barriers. Furthermore, the study provides an opportunity for the development of a "road map" aimed at achieving successful RL implementation. The remaining part of the paper is structured as follows: Section 2 presents a brief discussion of the results of the literature survey on critical barriers to the implementation of RL practices. The research methodology adopted is explained in Section 3 which is followed by discussion of the findings in Section 4. Section 5 is focussed on the implications of the study. Finally, Section 6 presents the recommendations and the conclusions.

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2. Literature review

2.1 Conceptualisation of the RL system

To facilitate the examination of the critical barriers faced by SA construction organisations, the concept of the RL system needs to be defined. This study draws upon the definition provided by Pokharel and Mutha (2009) wherein the RL system is visualised as being composed of three categories or components: inputs; processes and structure; and outputs. Accordingly, it is recommended that research on RL be structured and focussed by these categories. For example, Pokharel and Mutha (2009) state that as part of RL, the "processes and structure" are often associated with process optimisation or a location–allocation optimisation problem, whereas the outcomes of the RL system are the desired outputs in terms of remanufactured products, and recycled materials and spare parts (Pokharel and Mutha, 2009, p. 176). The following definitions of RL provided by various authors (Andel, 1997; Byrne and Deeb, 1993; Leite, 2003; Rogers and Tibben-Lembke, 1999; Tibben-Lembke and Rogers, 2002) are worth noting.

How the area of business logistics plans, operates and controls the flow of logistics information corresponding to the return of post-sale and post-consumption of the goods to the productive cycle through reverse distribution channels, adding value of various types to them: economic, ecological, legal, logistical, corporate image, etc. Leite (2003, cited in Nunes *et al.*, 2009, p. 3,717).

Rogers and Tibben-Lembke (1999) defined RL as:

> [t]he process of planning, implementing, and controlling the efficient, cost effective flow of raw materials, in-process inventory, finished goods, and related information from the point of consumption to the point of origin for the purpose of creating or recapturing value, or proper disposal (Rogers and Tibben-Lembke, 1999, p. 271).

The same definition was later simplified as follows: "[t]he movement of product or materials in the opposite direction for the purpose of creating or recapturing value, or proper disposal" (Tibben-Lembke and Rogers, 2002).

It is worth noting that some of the earlier seminal studies on RL also associated its definition with environmental aspects of the returned product (Andel, 1997; Byrne and Deeb, 1993).

2.2 barriers related to the implementation of RL

The literature on developing and developed countries across different industries such as services, manufacturing and construction is replete with studies on the major barriers affecting the implementation of RL. Drawing upon the approaches undertaken by Walker *et al.* (2008) from the private and public perspective and Ho *et al.* (2012), studies have aimed to examine the major factors that may influence industries to implement RL. These barriers can be categorised into internal (i.e. intra-organisational) and external (i.e. inter-organisational). Similarly, the seminal study by Carter and Ellram (1998), although focussed on the drivers rather than the barriers, conceptualised drivers into "internal" and "external" and linked "company factors" to internal with the "task environment" as external.

The following subsections present a brief discussion of the construction-specific literature in these identified categories:

2.2.1 Internal barriers

The major internal barriers to implementing RL within construction organisations include:

- considerable initial costs of adopting RL (Schultmann and Sunke, 2007a, 2007b);
- risks, uncertainties and potential liabilities for using recovered items (Addis, 2006a, 2006b), resulting in the lack of support in organisations (Gorgolewski, 2008; Srour *et al.*, 2012);
- operational complications such as the need to provide on-site space (Pun *et al.*, 2005), high labour costs (Sassi, 2004) and the demanding and time-consuming nature of RL (Schultmann and Sunke, 2007b); and
- lack of awareness regarding the potential advantages of RL for organisations (Chini and Bruening, 2003).

2.2.2 External barriers

The external barriers can be classified under two headings:

1. barriers imposed by the governing business environment in the industry, thus labelled "environmental barriers"; and
2. barriers due to the nature of construction products (e.g. buildings) and its activities.

These are discussed as follows:

2.2.2.1 Environmental-based barriers

- lack of recovery facilities, infrastructure and established used materials markets (Schultmann and Sunke, 2007b; Sinha *et al.*, 2010);
- lack of awareness of RL within the construction industry (Chini and Bruening, 2003; Sassi, 2004);
- lack of technical support (i.e. building standards, codes and guidelines) in favour of using recovered items (Greer, 2004; Sassi, 2008; Denhart, 2010);
- lack of financial and regulatory incentives (Addis, 2006a, 2006b; Leigh and Patterson, 2006);
- consumer culture and mindset about the lower quality of salvaged and used items (Chini and Bruening, 2003); and
- low costs of disposal of materials in landfill, thus not justifying the RL costs (Chini and Bruening, 2003).

2.2.2.2 Nature of construction products

- Long life cycle of buildings with different owners.
- Existence of hazardous substances; immobility and huge size of extracted materials; the difference in their deterioration rates and the vast variety in the quality of materials extracted from buildings (Kibert *et al.*, 2000a, 2000b; Schultmann and Sunke, 2007a, 2007b).
- Existing buildings are not designed for easy disassembly. Thus, the necessary time and labour for disassembly of buildings make RL an unattractive and unfeasible option (Kibert *et al.*, 2000b; Sassi, 2004).
- Wide variety and uncertainty of the location of points of origin in the RL system (buildings as the sources of used items) (Schultmann and Sunke, 2007b).

Similarly, Huscroft *et al.* (2013), while not focussed on identifying the barriers to RL implementation, identified the following seven key issues which are relevant for RL managers:

1. customer support;
2. top-management support;
3. communication;

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4 costs;
5 formalisation;
6 timing of operations; and
7 environmental issues.

Given the relevance of China as the largest developing country, as well as its contribution to waste generation from the construction industry perspective, some studies on barriers to RL from other industries are worth mentioning. Zhou *et al.*'s (2007) study within the battery manufacturing industry identified the following five barriers to RL:

1 lack of governmental policies;
2 lack of technical guidance and administrative resources;
3 lack of cost-effective recycling technologies;
4 lack of funding resources; and
5 lack of public participation.

A study by Hosseini *et al.* (2013) reviewed the barriers related to the implementation of RL within the manufacturing context. Tables I-III present a synthesis of the identified barriers under three categories: organisational; operational; and social (work) and environmental. Table I summarises the selected organisational-related barriers.

Table II summarises the selected operational-related barriers. Table III summarises the selected social (work) and environmental-related barriers.

Table I Major barriers associated with RL literature – organisational-related

Label	Description	References
OrgBri1	Higher costs of adopting RL	Jindal and Sangwan (2011), El Korchi and Millet (2011), Tan and Hosie (2010), Lau and Wang (2009), Del Brío and Junquera (2003), Hillary (2004), Post and Altma (1994), Zilahy (2004), Abdulrahman *et al.* (2014), Stock (1992)[a]
OrgBri2	Uncertainty about the results	Jindal and Sangwan (2011), González-Torre *et al.* (2010), Zilahy (2004), Roy and Vezina (2001), Huscroft *et al.* (2013)[a]
OrgBri3	Restraining organisational policies (e.g. overlooking DfRL)	Abdulrahman *et al.* (2014), Ravi and Shankar (2005), Rogers and Tibben-Lembke (1999), Richey *et al.* (2005b)[a]
OrgBri4	Lack of awareness within the organisation	Jindal and Sangwan (2011), Presley *et al.* (2007), Post and Altma (1994), Ravi and Shankar (2005)[a]
OrgBri5	Immaturity and low investment in knowledge management and information systems	Zhu *et al.* (2008), Ji (2006), Ravi and Shankar (2005), Ojha *et al.* (2013)[a], Rogers and Tibben-Lembke (1999, 2001)
OrgBri6	Lack of human resources with necessary qualifications and experience	Ravi and Shankar (2005), Hillary (2004), Post and Altma (1994), Daugherty *et al.* (2001)[a], Grawe (2009)[a], Jack *et al.* (2010)[a,,b]
OrgBri7	Inappropriate organisational structure (and size)	González-Torre *et al.* (2010), Post and Altma (1994)
OrgBri8	Lack of support from management	Jindal and Sangwan (2011), Zhu *et al.* (2008), Ravi and Shankar (2005), Daugherty *et al.* (2001, 2002)[a], Huscroft *et al.* (2013)[a], Skinner *et al.* (2008)[a], Rogers and Tibben-Lembke (2001)
OrgBr9	RL is not a priority in the organisations investment	Presley *et al.* (2007), (Rogers and Tibben-Lembke (1999, 2001)
OrgBri10	Resistance to change in the organisation	Jindal and Sangwan (2011), Ravi and Shankar (2005), Hillary (2004), Post and Altma (1994)

Notes: [a]Additional references to Hosseini *et al.* (2013) and Chileshe *et al.* (2014); [b]Jack *et al.* (2010, p. 232) defines resources commitment as consisting of the financial, technical and managerial resources that are committed to RL capabilities
Sources: Hosseini *et al.* (2013); Chileshe *et al.* (2014)

Table II Major barriers associated with RL literature–operational-related

Label	Description	References
OperBri1	Deficient structure of the industry for adopting RL	Qiang *et al.* (2013), Del Brío and Junquera (2003), Rogers and Tibben-Lembke (2001), Post and Altma (1994)
OperBri2	Lack of support from parties in the supply chain	Qiang *et al.* (2013), Jindal and Sangwan (2011), González-Torre *et al.* (2010), Ji (2006), Ravi and Shankar (2005), Rogers and Tibben-Lembke (2001)
OperBri3	Inadequacy of technologies (emphasis on information communications technologies [ICTs])	Aitken and Harrison (2013)[a], Daugherty *et al.* (2002)[a], Gonzalez-Torre *et al.* (2010)[a], Hazen *et al.* (2014)[a], Jindal and Sangwan (2011), Ji (2006), Ravi and Shankar (2005), Roger and Tibben-Lembke (2001)[a], Richey *et al.* (2005b)[a]
OperBri4	Lack of standardised processes and lack of shared understanding of the best practices	Abdulrahman *et al.* (2014), Lau and Wang (2009)
OperBri5	Lack of knowledge in the industry	Jindal and Sangwan (2011), Ji (2006), Ravi and Shankar (2005), Huscroft *et al.* (2013)[a,,b]
OperBri6	Unfavourable business culture	Hillary (2004), Ojha *et al.* (2013)[a]

Notes: OperBri = Operational-related barrier; [a]additional references to Hosseini *et al.* (2013) and Chileshe *et al.* (2014); [b]lack of knowledge falls under the theme of "Formalisation" in the Huscroft *et al.* (2013) study and relates to the adequate provision of the knowledge to implement the RL program
Sources: Hosseini *et al.* (2013); Chileshe *et al.* (2014)

Table III Major barriers associated with (RL literature–social (work) and environmental-related

Label	Description	References
SocBri1	Perceptions about the low quality of products of RL	González-Torre *et al.* (2010)
SocBri2	Lack of support from professional associations, non-government organisations, etc.	Hillary (2004)
SocBri3	Inappropriate governmental regulations	Carter and Ellram (1998)[a], Jindal and Sangwan (2011), González-Torre *et al.* (2010), Tan and Hosie (2010)
SocBri4	Bureaucratic problems in granting of licences and location permits	Zilahy (2004)

Notes: SocBri = Social-related barriers; [a]additional references to Hosseini *et al.* (2013) and Chileshe *et al.* (2014)
Sources: Hosseini *et al.* (2013); Chileshe *et al.* (2014)

The summarised main barriers in Tables I-III are illustrated in accordance with the three sub-classifications in five main groups in Figure 1:
1 operational barriers;
2 barriers related to the nature of buildings; products and returned materials;
3 industry-based barriers;
4 regulatory barriers; and
5 barriers relevant to local business practices.

Abdulrahman *et al.* (2014) grouped the RL implementation barriers relevant to the Chinese context into the following four categories:
1 management;
2 financial;
3 policy; and
4 infrastructure.

3. Research methods

A mixed methods approach was adopted to identify and rank the critical barriers that can affect the implementation of RL in the SA construction industry, and to determine the interaction among the sub-groupings of these identified critical barriers. The study design involved the following stages: exploratory survey research; descriptive survey research; and empirical survey research. It should be noted that a similar detailed description of these stages has been provided by the same authors in another study which aimed to investigate the factors that drive construction organisations to implement RL practices. This kind of replication is acknowledged in the literature. For example, Kunhui *et al.* (2013) adopted a similar sampling configuration as was used in the study by Lu *et al.* (2008) and, rather than providing the details associated with the research procedure, simply referred readers to the Lu *et al.* (2008) study.

- *Exploratory survey research*: This stage involved an extensive literature review on the critical barriers to RL implementation. The approach adopted was based on structuring and classifying the barriers drawn from the manufacturing and construction sectors into three groupings as follows: organisational; operational; and social (work) and environmental-related barriers. The results are reported in Tables I-III. Some discussions on the barriers as reported from other major countries such as China and India are included in the reviewed literature. Another objective associated with this stage was to review the existing methodologies applied in previous RL and supply chain management (SCM)-related literature. The underlying aim was, first, to identify the existing inadequacies and limitations of the reported methodologies and, second, to identify the gap and the benefits of employing refined statistical techniques. These would contribute to the theoretical RL knowledge base. As observed by Forza (2002, p. 152), this kind of survey (exploratory) is carried out using data collected in previous studies.
- *Descriptive survey research*: The second stage aimed to understand the relevance of the RL phenomenon and to describe the distribution of this phenomenon in a population (Forza, 2002, p. 155). To undertake the descriptive survey research, a robust questionnaire was developed based on the drivers identified in the first-stage exploratory survey research. The outcome was evaluated through a descriptive analysis, in accordance with Doloi *et al.* (2012), by investigating the trends of perceptions of certain industry practices based on first-hand experiences of practitioners. The questionnaire was subsequently administered to randomly selected contractors operating in the Adelaide region of South Australia. The main purpose was to present a survey of the perceptions of the barriers to implementing RL practices in SA construction organisations.
- *Empirical survey research*: The last stage was to conduct the empirical research. This involved the computation of the relative agreement index (RAI) values and correlation analysis to evaluate the strength of relationships among the RL barriers. As stated by Forza (2002), this stage or type of research is associated with testing the adequacy of concepts (in this case, the barriers to implementing RL) and any hypothesised linkages among the concepts (Forza, 2002, p. 155). This would provide a further opportunity to generate empirical contributions. As Summers (2001), p. 401 states, the nature of a study's contribution can be conceptual, empirical or methodological. The current study's detailed contributions will be discussed in Section 6.

The adoption of these three different approaches to survey research is indicative of triangulation through the mixed methods approach. The justification for adopting a triangulated approach within construction management research and other disciplines is well documented within the literature (Ammenwerth *et al.*, 2003; Chileshe and

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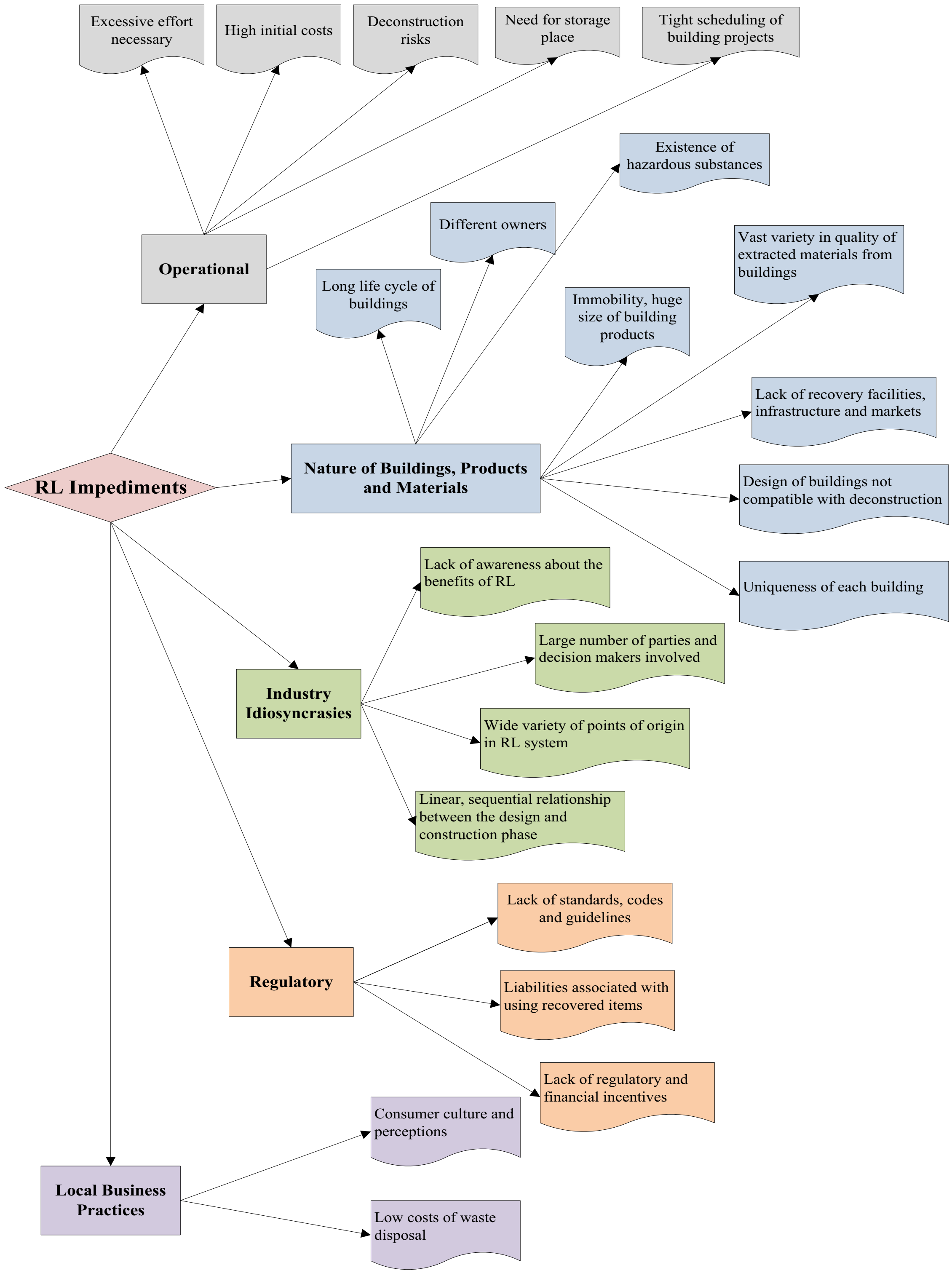
Figure 1 Major barriers to implementing RL within the construction industry



Source: Hosseini *et al.* (2014a)

Watson, 2005; Jack and Raturi, 2006; Selviaridis and Spring, 2007). The benefits of triangulation range from having completeness in the results, and being contingency-driven by the need for insights into how and why a particular strategy is chosen (Jack and Raturi, 2006, p. 346). According to Ammenwerth *et al.* (2003), this enables the "validation of results (convergence)" and "completeness of results (complementary)". From the RL perspective, Mangan *et al.* (2004) indicate how methodological triangulation provides multidimensional insights into many management research problems.

The specific objectives of the current study were to:

- identify and rank the critical barriers to implementing RL in the SA construction sector;
- establish the interaction between identified critical barriers to implementing RL using correlation analysis; and
- to discuss the managerial, society, research, practice, academic and government implications for this study and provide some recommendations for future research.

3.1 Measurement instrument

The questionnaire, that is, the measurement instrument, was divided into four sections as follows:

3.1.1 Section 1

General demographics of respondents (included organisational characteristics such as the number of employees, type of construction work undertaken, main role (or organisation), years in existence (of the organisation) and the individual's characteristics such as their position designation and tenure). The significance and importance of including such demographical or control variables are highlighted by Ho *et al.* (2012) who proposed a framework for RL implementation. The emergent framework comprised three dimensions:

1. background information of the company;
2. recognition and perception of RL; and
3. internal and external factors.

For example, according to Ho *et al.* (2012), organisation size, as represented in the first dimension, was found to play a significant role in RL implementation. Similarly, the study reported and found linkages between the motivation towards RL and the control or demographical variables of "business field" and "role in supply chain".

3.1.2 Section 2

Evaluation of current RL practices. This section was aimed at examining the practices that were desirable for RL as conceptualised at these three levels: project; organisation; and industry. Respondents were asked to rate their levels of agreement using a 5-point Likert scale where 1 = strongly disagree; 2 = disagree; 3 = neutral; 4 = agree; and 5 = strongly agree.

3.1.3 Section 3

Drivers for incorporating DfRL in the building life cycle. Respondents were asked for their perceptions based on the organisational context for the ten drivers identified in the literature review.

3.1.4 Section 4

Barriers to implementing RL in building projects. Similar to the aim of the drivers' sub-instrument, this section was aimed at investigating the factors inhibiting (barriers to) the implementation of RL with this leading to the findings reported in this study. The main purpose of this section was to address the first objective of the study, namely, to identify and rank the critical barriers to implementing RL in the SA construction sector. The 16 barriers were structured into three categories: operational barriers ($n = 7$); industrial barriers ($n = 5$); and social barriers ($n = 4$). The question posed to respondents was:

> [p]lease indicate your firm's level of agreement with the following statements provided regarding the barriers to implementing RL in building projects. Please read each statement carefully and tick the appropriate box (Key where 5 = strongly agree (SA); 4 = agree (A); 3 = neutral (N); 2 = disagree (D); and 1 = strongly disagree (SD).

To avoid biased reporting, respondents were required to think of a project that involved aspects associated with RL as a frame of reference for completing their questionnaire. The full listings of the questions are shown in Appendix 1.

The statements for the 16 barriers are presented in Tables VIII-X. For the three sub-instruments (practices, drivers and barriers), a ratio from a difference of 1-5 (4) and agreement intervals of 0.8 were used to discuss the degree of central tendency resulting in the following:

- $1.00 \leq$ "strongly disagree" (SD) ≤ 1.80;
- $1.80 <$ "disagree" (D) ≤ 2.60;
- $2.60 <$ "neutral" (N) ≤ 3.40;
- $3.40 <$ "agree" (A) ≤ 4.20;
- $4.20 <$ "strongly agree" (SA) ≤ 5.00.

A similar approach for the generation of intervals was used by Kazaz and Ulubeyli (2007) in a study aimed at investigating the drivers of productivity. Drawing heavily from Pinto and Covin (1989), their study's respondents were required to think of a project in which they had been involved to create a frame of reference for completing their questionnaire (Pinto and Covin, 1989, p. 56). The findings reported within this paper only relate to Sections 1 and 4, the latter being the aspects that deal with barriers. It is beyond the scope of this paper to report on all the issues that were covered within the research project. Furthermore, the information related to practices (Section 2) and drivers (Section 3) are presented in other papers by the same authors. For example, these findings are already published in Chileshe *et al.* (2014) and summarised in Tables VIII-X.

3.2 Population frame and sample size

The population frame for this research is as reported in Chileshe *et al.* (2014) and comprised contractors, demolishers, salvage-related organisations and members of the Civil Contractors Federation (CCF) of South Australia and the Master Builders' Association. One major requirement was that the organisations had to be located and operating from Adelaide, South Australia. By selecting organisations from these two associations, this study sought to control the industry effects. As observed by Sharp *et al.* (2013, p. 46), empirical findings and the interpretation of theoretical models can differ based on how industry effects are incorporated. Given that the majority of the literature and the subsequently utilised RL barriers were drawn from manufacturing studies, it was important to minimise the industry effects. Furthermore, it should be noted that the collected data were part of a larger study associated with DfRL within the building life cycle which explored practices, drivers and barriers. Table IV depicts the summary of the questionnaire responses according to the two modes of distribution (email and postal survey).

Emails were sent to 260 contractors and 26 demolition sub-contractors (a total of 286) and, after a month and a half, a reminder was sent to the same respondents which resulted in

Table IV Profile of questionnaires distributed

Mode of administration	Distributed	Completed	Response rate (%)
Email survey[a]	286	23	8.04
Post survey[b]	260	26	10.27
Total	539	49	9.09

Notes: [a]The 286 email questionnaires were distributed to 260 contractors and 26 demolition sub-contractors; [b]the total number postal survey questionnaires used for calculating the response is 253, as the it takes into the incomplete and returned due to wrong mailing addresses

23 duly completed online questionnaires. A further 260 survey questionnaires were sent by post to construction companies. Of the 260 that were sent, 4 were returned due to issues associated with the addresses, while 3 targeted respondents sent letters of apology, as they elected not to participate due to lack of knowledge. Altogether, 29 questionnaires were returned, resulting in 26 duly completed usable responses. In all, 49 completed questionnaires were used in the results analysis, representing a 9.09 per cent response rate. While this number might be deemed small when compared to the overall population of contractors within the selected sample, in comparison with previous studies (Lim and Ling, 2012; Yong and Mustaffa, 2012), this sample size was adequate. For example, the study by Lim and Ling (2012) had a sample size of 32 respondents, whereas Yong and Mustaffa (2012) employed a smaller sample size of 14 respondents.

3.3 Data collection method

In keeping with the sampling strategy, the following techniques were used to design and distribute the questionnaires:

1. An electronic questionnaire was developed on the University of South Australia (UniSA) website and the following professional bodies representing construction managers and builders were asked to distribute it to their members:
   - Australian Institute of Building;
   - Australian Institute of Project Management; and
   - Australian Institute of Architects.
2. A hard-copy questionnaire was prepared and sent directly to the following:
   - members of CCF of South Australia;
   - Master Builders' Association of South Australia; and
   - demolition sub-contractors.

The rationale for using the questionnaire sample survey was to capture data associated with perceptions. As expressed by Henn *et al.* (2006, cited in Olusanjo *et al.*, 2013, p. 130), among the types of data gathered in quantitative research are those of "perceptions", implying what people think and feel about certain things. This questionnaire sample survey was, therefore, deemed as appropriate as the purpose of the study was to capture the perceived barriers to implementing RL practices.

3.4 Analysis of results

The five analyses of the collected data were conducted as follows: ranking analysis; Spearman's rank correlation; coefficient of determination; (iv) RAI; and coefficient of variation (CV). These are discussed in the following subsections:

3.4.1 Ranking analysis

To achieve the first objective, namely, "to identify and rank the critical barriers to implementing RL in the SA construction sector", ranking analysis was employed. The underlying objective of this analysis was to ascertain the relative importance of the critical barriers to implementing RL in the SA construction sector (Table I) through the examination of descriptive statistics in Tables VII through XI (mean score values, standard deviation and CV). As with previous studies (Yuan *et al.*, 2011; Doloi *et al.*, 2012), rank differentiation where two or more barriers had the same mean values was achieved through examination and selection of the variable (or barrier) with the lowest standard deviation or CV. Based on the classification used to discuss the degree of central tendency, a benchmark of 3.40 was used to identify the barriers that were significant. It should, however, be noted that different approaches exist in the literature for ascertaining the cut-off points when the 5-point Likert scale is used to measure levels of agreement. For example, Yuan *et al.* (2011) adopted the cut-off mean value of 3.00.

3.4.2 Pearson's correlation (r)

To achieve and meet the second objective, namely, "to establish the interaction between identified critical barriers to implementing RL using correlation analysis", the strength of the relationships between the variables was examined by using Pearson's correlation (r) value, also known as the *product–moment coefficient*. According to Babbie *et al.* (2013), the range of the value of Pearson's r is from -1.00 to $+1.00$, indicating both the strength and direction of the relationship between two interval (I)/ratio (R) variables. Its main purpose is to determine the existence and strength of relationships between the critical barriers (Forza, 2002). Some studies such as Cohen (1988, cited in Pallant, 2005) have suggested the following guidelines for interpretation of the correlation (r) values:

- $r = 0.10$ to 0.29 or -0.10 to -0.29 (small);
- $r = 0.30$ to 0.49 or -0.30 to -0.49 (medium); and
- $r = 0.50$ to 1.0 or -0.50 to -1.00 (large).

It should be pointed out that there are varied interpretations of the correlation values for Pearson's coefficients. For example, a study conducted by Assaf *et al.* (2010) aimed to discuss the main factors affecting the construction cost of affordable housing in Saudi Arabia used the following classifications:

- -1.0 to -0.7, strong negative association;
- -0.7 to -0.3, weak negative association;
- -0.3 to $+0.3$, little or no association;
- $+0.7$ to $+0.3$, weak positive association; and
- $+0.7$ to $+1.0$, strong positive association.

3.4.3 Coefficient of determination (r^2) or amount of variance

To examine the amount of variance between two variables, the coefficient of determination (r^2) was computed by squaring the value of Pearson's correlation (r) coefficient. According to Babbie *et al.* (2013), the coefficient of determination is a proportionate reduction of error measure. It provides the proportion of reduced errors by including the independent

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variable in the prediction of the dependent variable for interval/ratio variables (Babbie *et al.*, 2013, p. 445), with the value of the coefficient of determination (r^2) ranging from 0 to 1.0. The classification of the coefficient of determination (r^2) values is similar to those of Pearson's correlation (r), as discussed in the preceding section.

3.4.4 Relative agreement index

Recent studies in construction management (Ahmed and Hassan, 2003; Chileshe and Watson, 2005; Holt, 2014) and in allied disciplines such as project management (Doloi *et al.*, 2012) have urged caution in the usage of descriptive statistics such as the mean score and standard deviation when ranking variables. For example, Ahmed and Hassan (2003) have pointed out that the mean values cannot be used to compare the levels of different categories, while Doloi *et al.* (2012) and other studies have equally acknowledged the need to undertake such analysis. The lack of meaning in terms of understanding the clustering effects of similar attributes remains a source of concern (Doloi *et al.*, 2012, p. 481; Holt, 2014). To overcome this weakness, the RAI value is derived to summarise the criticality of each barrier to the implementation of RL using the following equation:

$$\text{RAI} = \frac{\sum W}{AXN}$$

where:

W = weighting as assigned by each respondent in a range of 1 to 5, where 1 implies "strongly disagree" and 5 implies "strongly agree";

A = the highest weight (5); and

N = the total number in the sample.

A low RAI value indicates that the critical barrier is considered of less significance by respondents, whereas a high index value indicates the higher and more critical influence of that barrier in RL implementation. If the RAI values were the same for two or more critical barriers or variables, examining the distribution of the rating against such variables achieved rank differentiation. A similar approach was used previously by Doloi *et al.* (2012) to compute the mean score.

3.4.5 Coefficient of variation

The CV is used as a general measure of the standardised skewness of the response. This is similar to the Importance Index utilised by Pongpeng and Liston (2003). Other previous studies that employed the CV are those by Zakeri *et al.* (1997) and Mahamid (2012).

$$\text{CV} = \frac{\text{Standard deviation of score on dimension or barrier}}{\text{Mean of scores on dimension or barrier}}$$

The inference to be drawn is that a high average score with a low CV on an RL dimension is used as an indicator of a significant RL barrier. It could further be argued that the CV on a particular dimension, expressed as a percentage, can be used as a measure of consistency with regard to which companies in the industry adhere to that RL barrier.

4. Data analysis and findings

4.1 Reliability analysis and profile of the sample

The reliability and internal consistency of the composite survey instrument (comprising the 16 barriers to RL) were itemised in the preceding sections (Tables I through III), and were further categorised into the following three sub-groupings: operational barriers; industrial barriers; and social barriers. These were then examined using Cronbach's alpha coefficient. According to Cronbach (1951), this is one of the most popular reliability statistics and aims to determine the internal consistency or average correlation of items in a survey instrument to gauge its reliability. The summary of these results is reported in Table V.

The composite Cronbach's alpha coefficient for the 16 items was found to be 0.887 (F-statistic = 8.002; sig. = 0.000) with the standardised item alpha of 0.888. This is above the acceptable value of 0.7, thus indicating a high reliability for the scales (Nunnally, 1978). As can be seen from Table V, the Cronbach's alpha coefficients for the three sub-instruments ranged from 0.820 to 0.823, whereas the Cronbach's alpha coefficients based on standardised items ranged from 0.821 to 0.826. The above values demonstrate that the sub-instruments were above the threshold and, therefore, were held to be reliable.

4.2 General characteristics of respondents

The majority (27; 56.3 per cent) of respondents were employed at executive level, followed by the next largest group which was project managers (8; 16.7 per cent). In terms of experience, the majority (56.3 per cent) of respondents had more than 20 years of experience followed by 31.3 per cent who had from 11-20 years' experience. Cross-tabulation of the data was conducted to examine the relationship between the designation of respondents within their respective organisations and their years of experience. The cross-tabulation results are reported in Table VI where it is shown that 18 of the 27 respondents with more than 21 years of experience were at executive level (i.e. chief executive officer [CEO], president and vice president). The results also revealed that 93.75 per cent of respondents had a combined range of experience of from 6-20 years (6-10 [6.25 per cent]; 11-20 [31.25 per cent]); or over 21 years (56.25 per cent).

Table V Summary of reliability statistics for the sub-instruments for the barriers to implementing RL

No.	RL barriers instrument	N[b]	No. of items	Cronbach's α	Cronbach's α based on SI	F (p)[c]
1	Composite barriers[a]	49	16	0.887	0.888	8.002 (0.000)
2	Operational	48	7	0.823	0.826	7.475 (0.000)
3	Industrial	48	5	0.821	0.821	10.740 (0.000)
4	Social	48	4	0.820	0.822	8.513 (0.000)

Notes: [a]The composite factors is the aggregate of the three sub-instruments, namely, operational-related barriers; industrial-related barriers; social-related barriers (see Figure 1); SI = standardised Items; [b]total number of responses less listwise deletion based on the variables in the procedure (N = 49); [c]the values in parentheses and italics are the significance based on the ANOVA output

Table VI Cross-tabulation of respondents' positions (designations) and years of experience

Count Position in organisation	Position in organisation × years of experience Years of experience <5 years	6-10	11-20	Over 21	Total
Executive/(CEO, president, vice president)	1	0	8	18	27
Project manager	2	2	1	3	8
Construction manager	0	0	1	0	1
Field superintendent	0	0	1	1	2
Supervisor	0	0	2	0	2
Site engineer	0	0	1	2	3
Other*	0	1	1	3	5
Total	3	3	15	27	48

Note: *Representing 5 (10.4%) other category of senior management

The profile of the sample in terms of organisational characteristics (type of construction work; sub-sector and size; and experience) is reported in Table VII.

As shown on Table VII, the majority (89.9 per cent) of respondents were drawn from small- and medium-sized enterprises (SMEs) (i.e. those with less than 114 employees). The remaining five (10.2 per cent) were from large organisations. Given this study's focus on investigating barriers affecting the implementation of RL, it was considered appropriate to include SMEs. Of the firms across the three sectors within the construction industry that contribute to the generation of over half of the C&I, about 19 per cent are SMEs (Zero Waste, 2011). This finding is further supported by the Construction Industry Workforce Action Plan Reference Group's (2009) report which acknowledged that there are approximately 30,000 building and construction businesses in SA, with 96 per cent of them employing less than 20 people and 75 per cent being non-employing businesses. Table VII also shows that the majority (15; 30.6 per cent) of these businesses were contractors followed by sub-contractors (11; 22.4 per cent).

Table VII Profile of study sample (organisational characteristics)

Characteristics	No. of respondents[a]	(%)	Cumulative
Principal type of construction work (CW)			
Commercial	6	12.5	12.5
Residential	7	14.6	27.1
Industrial	4	8.3	35.4
Public Works	5	10.4	45.8
More than two types of CW	15	31.3	77.1
More than three types of CW	6	12.4	89.5
Other[e]	5	10.4	100.0
Main role (sector)			
Designer and builder	1	2.0	2.0
Contractor	15	30.6	32.7
Sub-contractor	11	22.4	55.1
Specialised contractor	9	18.4	73.5
More than two roles[b]	9	18.4	91.1
More than three roles[c]	3	6.1	98.0
Other[e,,a]	1	2.0	100.0
Length of activity in the building industry (years)			
< 5	4	8.2	8.2
6–10	7	14.3	22.4
11–20	16	32.7	55.1
Over 21	22	44.9	100.0
Number of employees[d,,e]			
< 24	32	65.3	65.3
25-114	12	24.5	89.9
>115	5	10.2	100.0

Notes: [a]Where respondents selected all the four categories of designer and builder, contractor, sub-contractor, and specialised contractor; [b&c]where respondents selected from either designer and builder, contractor' sub-contractor and specialised contractors; [d]based on average number of employees per year; [e]Ho *et al.* (2012) found organisation (company) size to have a significant relationship with RL implementation

4.3 Overall ranking of the barriers

This subsection examines construction stakeholders' perceptions of barriers inhibiting RL implementation. Table VIII summarises the results of the analysis of the barriers based on the overall sample.

As shown on Table VIII, the mean scores of the 16 barriers inhibiting the implementation of RL ranged from 3.143 (OperBri3 = "incompatible design for deconstruction") to 3.5625 (InduBri2 = "lack of incorporation of salvaged materials in design of building") with an average score of 3.090 and a range of 1.000. In contrast, the standard deviation of all 16 of the variables (barriers) ranged from 0.7457 to 0.9557, the highest standard deviation being "my organisation (firm) would not support deconstructing buildings because existing buildings are not designed to be deconstructed" (OperBri4: standard deviation = 0.95565). The lowest standard deviation was the operational barrier "my organisation (firm) would not deconstruct because deconstruction takes detailed planning and needs extra effort compared to demolition" (OperBri5: standard deviation = 74,574). Table VIII also shows different values for the minimum and maximum scores, suggesting that the data and sample were not biased.

However, it should be noted that in discussing the overall ranking of the barriers in the different categories (as shown in Tables IX-XI), the approach undertaken is that of selecting only the top-ranked barriers. As pointed out in the study by Chileshe and Kikwasi (2014), albeit the study's focus being on risk management, the rationale for this approach of selecting only the top-ranked barriers is to enable a more detailed discussion of the

Table VIII Overall ratings of barriers to implementing RL

Barrier[a]	Min	Max	MS[b]	SD	CV[c]	RAI[d]	Rank[e]	Overall ranking
OperBri1	1.00	5.00	3.292	0.9354	28.68	0.6583	1	=4
OperBri2	2.00	4.00	3.292	0.9354	28.68	0.6583	1	=4
OperBri3	1.00	5.00	2.592	0.9557	36.87	0.5184	7	16
OperBri4	1.00	5.00	2.776	0.7710	27.78	0.5551	5	13
OperBri5	1.00	5.00	2.837	0.7457	26.29	0.5667	4	12
OperBri6	1.00	4.00	2.776	0.7710	27.78	0.5551	5	13
OperBri7	1.00	5.00	3.000	0.8752	29.17	0.6000	3	10
IndsBri1	1.00	5.00	3.163	0.9431	28.91	0.6327	3	7
IndsBri2	2.00	5.00	3.563	0.8482	23.81	0.7125	1	1
IndsBri3	1.00	5.00	2.776	0.8232	29.66	0.5551	5	15
IndsBri4	1.00	5.00	3.1224	0.8811	28.22	0.6249	4	8
IndsBri5	1.00	5.00	3.417	0.9187	26.89	0.6833	2	3
SocBri1	1.00	5.00	2.878	0.7803	27.14	0.5755	4	11
SocBri2	2.00	5.00	3.167	0.9070	28.64	0.6333	2	6
SocBri3	1.00	5.00	3.021	0.8870	29.36	0.6042	3	9
SocBri4	2.00	5.00	3.449	0.8675	25.15	0.6898	1	2

Notes: Based on total number of 49 responses; where [a]OperBri = operational-related barriers; IndsBri = industrial-related barriers; SocBrI = social-related barriers; MS[b]= mean score of the barrier where 5 = strongly agree; 4 = agree; 3 = neutral; 2 = disagree; and 1 = strongly agree; the higher the mean, the more restrictive the barrier to implementing RL; CV[c] = coefficient of variation; RAI[d] = relative Agreement Index; [e]Individual ranking within the three sub-categories of barriers

Table IX Overall ratings of operational-related barriers to implementing RL

Barrier[a]	Min	Max	MS[b]	SD	CV[c]	RAI[d]	Rank[e]	Overall ranking
OperBri2	2.00	4.00	3.292	0.9354	28.68	0.6583	1	4
OperBri1	1.00	5.00	3.292	0.9354	28.68	0.6583	1	4
OperBri7	1.00	5.00	3.000	0.8752	29.17	0.6000	3	10
OperBri5	1.00	5.00	2.837	0.7457	26.29	0.5667	4	12
OperBri4	1.00	5.00	2.776	0.7710	27.78	0.5551	5	13
OperBri6	1.00	4.00	2.776	0.7710	27.78	0.5551	5	13
OperBri3	1.00	5.00	2.592	0.9557	36.87	0.5184	7	16

Notes: Based on total number of 49 responses; where [a]OperBri = operational-related barriers; MS[b] = mean score of the barrier where 5 = strongly agree; 4 = agree; 3 = neutral; 2 = disagree; and 1 = strongly agree; the higher the mean, the more restrictive the barrier to implementing RL; CV[c] = coefficient of variation; RAI[d] = relative Agreement Index; [e]individual ranking within the sub-categories of barriers

Table X Overall ratings of industrial-related barriers to implementing RL

Barrier[a]	Min	Max	MS[b]	SD	CV[c]	RAI[d]	Rank[e]	Overall ranking
IndsBri2	2.00	5.00	3.563	0.8482	23.81	0.7125	1	1
IndsBri5	1.00	5.00	3.417	0.9187	26.89	0.6833	2	2
IndsBri1	1.00	5.00	3.163	0.9431	28.91	0.6327	3	7
IndsBri4	1.00	5.00	3.122	0.8811	28.22	0.6249	4	8
IndsBri3	1.00	5.00	2.776	0.8232	29.66	0.5551	5	15

Notes: Based on total number of 49 responses; where [a]IndsBri = Industrial-related barriers; MS[b] = Mean score of the barrier where 5 = strongly agree; 4 = agree; 3 = neutral; 2 = disagree; and 1 = strongly agree; the higher the mean, the more restrictive the barrier to implementing RL; CV[c] = coefficient of variation; RAI[d] = Relative Agreement Index; [e]Individual ranking within the three sub-categories of barriers

advocated solutions, whereas the least ranked would be included to highlight the significance of the barriers. This then forms the basis for highlighting the contribution of the study and, subsequently, the attempt to distinguish the potential contribution of this paper from that of many other studies.

4.3.1 Overall ranking of operational-related barriers.
This subsection examines construction stakeholders' perceptions of the barriers inhibiting RL implementation. Table IX summarises the results of the analysis of operational-related barriers based on the overall sample.

As shown on Table IX, the mean scores of the seven operational-related barriers inhibiting RL implementation ranged from 2.592 (OperBri3 = "my firm would not support deconstructing buildings because existing buildings are not designed to be deconstructed") to 3.2917 (OperBri1 = "my firm is reluctant to deconstruct buildings due to the higher

Table XI Overall ratings of social-related barriers to implementing RL

Barrier[a]	Min	Max	MS[b]	SD	CV[c]	RAI[d]	Rank[e]	Overall ranking
SocBri4	2.00	5.00	3.449	0.8675	25.15	0.6898	1	3
SocBri2	2.00	5.00	3.167	0.9070	28.64	0.6333	2	6
SocBri3	1.00	5.00	3.021	0.8870	29.36	0.6042	3	9
SocBri1	1.00	5.00	2.878	0.7803	27.14	0.5755	4	11

Notes: Based on total number of 49 responses; where [a]SocBri = social-related barriers; MS[b] = mean score of the barrier where 5 = strongly agree; 4 = agree; 3 = neutral; 2 = disagree; and 1 = strongly agree; The higher the mean, the more restrictive the barrier to implementing RL; [c]CV = coefficient of variation; [d]RAI = relative Agreement Index; [e]individual ranking within the three sub-categories of barriers

costs involved compared to demolishing") with an average mean score of 2.943 and range of 0.688. In contrast, the standard deviation of all seven of the operational-related barriers ranged from 0.5184 to 0.6570. The highest standard deviation was "my firm is reluctant to deconstruct buildings due to the higher costs involved compared to demolishing" (OperBri1: standard deviation = 0.6570), while the lowest standard deviation was the operational barrier "my firm would not support deconstructing buildings because existing buildings are not designed to be deconstructed" (OperBri3: standard deviation = 0.5184).

4.3.1.1 Lengthy period for the implementation of deconstruction and higher costs. Table IX indicates that the two barriers of "my firm is reluctant to deconstruct buildings due to the higher costs involved compared to demolishing" and "because it takes a longer time to implement" were jointly top ranked barriers (mean score = 3.292; RAI = 0.6583). The impact of higher costs for RL implementation is consistent with the findings in the literature review (Abdulrahman *et al.*, 2014; Daugherty *et al.*, 2001; Del Brío and Junquera, 2003; El Korchi and Millet, 2011; Genchev *et al.*, 2011; Hillary, 2004; Ho *et al.*, 2012; Jindal and Sangwan, 2011; Lau and Wang, 2009; Post and Altma, 1994; Richey *et al.*, 2005a; Tan and Hosie, 2010; Zilahy, 2004). For example, Abdulrahman *et al.*'s (2014) investigation of the critical barriers to implementing RL in the Chinese manufacturing sector identified the "lack of the initial capital" as one of the biggest financial barriers. Similarly, a study undertaken by Ho *et al.* (2012) among Hong Kong businesses identified the financial aspect as having an important role in RL implementation. According to Lau and Wang (2009), the significant costs associated with adoption of RL in organisations acts as the primary impediment to starting to use RL in the supply chain of an organisation. Relative to the higher costs involved in deconstruction (OperBri1), some studies such as those by da Rocha and Sattler (2009) and Sinha *et al.* (2010) have suggested the elimination of risks and uncertainties as an avenue for reducing the costs of the RL system. Similarly, some studies have suggested that RL processes could possibly reduce transportation and inventory costs (Daugherty *et al.*, 2002). This finding suggests that the SA construction organisations could benefit by integrating some activities in risk management and assessment processes when considering implementing an RL system. One such example is associated with the first step of risk assessment, namely, that of auditing the environment, as an RL system would provide the organisation with opportunities to identify the prevailing conditions (uncertainties) within the operating environment. The study by Skinner *et al.* (2008) also highlighted the importance of a strategic fit between a firm's internal strengths and weaknesses and the external environment. It should be pointed out that exploration through the use of the strengths, weaknesses, opportunities and threats (SWOT) analysis is normally undertaken as part of the first stage (auditing of the environment) of the risk assessment process.

4.3.1.2 Timely availability of required materials and products. The third highest ranked barrier overall was that of "lack of organisational support in using salvaged materials due to the timely availability of required materials and products", (mean score = 3.000; RAI = 0.6000). This barrier was also ranked tenth in the full listing (see Table VIII). The importance of timely availability of materials has been acknowledged in the literature (Schultmann and Sunke, 2007b; Olorunniwo and Li, 2010; Huscroft *et al.*, 2013; Abdulrahman *et al.*, 2014). For example, Schultmann and Sunke (2007b) observed that among the complications associated with implementing RL was the necessity of continuous planning due to changes in time and location of collection points. This takes extra effort compared to demolishing buildings and purchasing virgin materials, while Huscroft *et al.* (2013) identified and attributed the timing of operations as being indirectly related to vertical coordination and customers.

In the context of China, Abdulrahman *et al.* (2014) categorised RL barriers into the following four types: management; financial; policy; and infrastructure. The barrier of "timely availability of required materials and products" is similar to the type found within their infrastructure category, of "limited forecasting and planning". The above result highlights the need for SA construction organisations to pursue effective practices as advocated by Addis (2006a), such as the early provision of design information. Accordingly, this would assist suppliers to find appropriate products and materials. The same study by Addis (2006a), although based on Canadian and UK experiences, further recommended the need to establish a network of links between the new development parties and local contractors and suppliers as necessary. Other mechanisms that could be pursued by SA construction contractors in overcoming this barrier can be found in the suggestions by Gorgolewski (2008) and Hiete *et al.* (2011). These two studies highlighted the need to factor in the level of demand for recovered materials in the region when considering implementing RL activities on a large scale. Conversely, Olorunniwo and Li (2010) highlighted the importance of the extent of collaboration and impact of information sharing and their impact on RL performance. The same study argued for the same level of cooperation as conducted in forward logistics and cautioned regarding the relevance of customers, given that they make the final decision on orders and returns (Olorunniwo and Li, 2010, p. 455). Recent studies such as the work of Hosseini *et al.* (2013) aim to set the research agenda for RL and propose the establishment of partnering arrangements among the strategies for enhancing and improving the exchange of information or the incorporation of DfRL by the designers.

4.3.2 Overall ranking of industrial-related barriers

This subsection examines construction stakeholders' perceptions of the barriers inhibiting the implementation of RL. Table X summarises the results of the analysis of industrial-related barriers based on the overall sample.

As shown on Table X, the mean scores of the five industrial-related barriers inhibiting the implementation of RL ranged from 2.7755 (IndsBri3 = *my firm would not support using salvaged materials as the overall costs of salvaged materials is higher than using virgin products*) to 3.5625 (IndsBri2 = *my firm would not use salvaged materials as the designers do not incorporate using salvaged materials in their design proposals*) with an average mean score of 3.208 and range of 0.792.

4.3.2.1 Limited usage of salvaged materials due to lack of design considerations. The organisation's reluctance to use salvaged materials due to the lack of design incorporation is also ranked as the most important critical barrier within this category of "industrial barriers" based on all 16 barriers (mean score = 3.5625; RAI = 0.7125). Support for the high ranking of this critical barrier can be found in previous studies such as manufacturing-related studies (Abdulrahman *et al.*, 2014; Ravi and Shankar, 2005; Rogers and Tibben-Lembke, 1999) and construction-related studies (Kibert *et al.*, 2000b; Sassi, 2004; Addis, 2006a; Chini and Bruening, 2003; Zero Waste, 2011; Srour *et al.*, 2012). For example, Addis (2006a) observed that considerations for using reclaimed materials and products should be incorporated by designers, and the relevant information on design issues should be communicated to the contractors and the client. The study by Zero Waste (2011) also identified the "time lag between demand and supply of recycled materials for large projects" as one of the challenges associated with C&D. The implication arising from this finding is that as a measure to mitigate these barriers, designers could play a significant role in promoting RL, as they are the key decision-makers when it comes to the use of salvaged materials and products in building specification, contracts and designs (Chini and Bruening, 2003; Srour *et al.*, 2012). This study further suggests that designers, in "implementing design for deconstruction (DfD)" or DfRL initiatives as part of the actual design of the buildings, should take into account the intention to deconstruct and reuse the products and materials of the buildings. The proposed strategy would assist in the development of policies for key players (such as designers) and, in turn, would contribute towards the promotion and implementation of RL within the construction industry.

4.3.2.2 Limited usage of recovered materials and components due to restrictive regulations. The second highest ranked barrier overall was that of "my firm would not use salvaged materials as regulations confine the use of recovered materials and components in building projects" (mean score = 3.4167; RAI = 0.6833). This barrier was also ranked second based on the full listing (see Table VIII). This finding is also consistent with the literature in manufacturing-related studies (Jindal and Sangwan, 2011; Abdulrahman *et al.*, 2014; González-Torre *et al.*, 2010; Tan and Hosie, 2010) and construction-related studies (Addis, 2006a, 2006b; Leigh and Patterson, 2006). The implication from this finding is that both the government and policymakers have a role to play to overcome this barrier. For example, regulatory and financial incentives should justify the adoption of RL in the construction industry. Moreover, inclusion of RL and deconstruction, and introducing standards for recovered materials in building codes and technical regulations would eliminate the risks perceived by designers and builders.

4.3.3 Overall ranking of social-related barriers

This subsection examines construction stakeholders' perceptions of the barriers inhibiting the implementation of RL. Table XI summarises the results of the analysis of social-related barriers based on the overall sample.

4.3.3.1 Limited usage of salvaged materials due to potential legal liabilities and adverse consequences. The organisation's reluctance to use salvaged materials due to the potential legal liabilities and adverse consequences was ranked as the most important critical barrier within this category of "social barriers" and achieved a third ranking among all 16 barriers (mean score = 3.449; RAI = 0.689). Some of the legal aspects reported in the literature are associated with holding the risks inherent in the integrity and performance of reclaimed products (Addis, 2006a; Leigh and Patterson, 2006). Some studies such as those by Sassi (2004) and Guy and McLendon (2002) have identified and linked the issue of adverse consequences due to the emphasis on health and safety. Accordingly, this has contributed to contractors' reluctance to use recovery practices due to increases in the associated costs.

Despite the higher ranking of this barrier, the existence of supporting regulations within the SA context should, however, be noted. These guiding principles are mainly intended to ensure that resource recovery is suitable for an intended beneficial use, whilst maximising value and minimising any adverse impacts. Furthermore, one implication emerging from this finding about "potential legal liabilities and adverse consequences" is that to overcome this barrier, thus promoting the usage of salvaged materials, a better mechanism needs to be in place for adopting some practices. For example, a study undertaken in the UK by Addis (2006a) demonstrated that it is possible for contractual issues to be addressed in the initial stages of design. This has the ability to organise the liability and to program matters pertaining to using reclaimed material, increasing the understanding of the issues at hand. Similarly, some studies undertaken in British Columbia, Canada and the USA(Addis, 2006a; Leigh and Patterson, 2006) have suggested that the "establishment of a partnership between all the parties involved is necessary for the success of the projects with RL".

4.3.3.2 "Dislike of salvaged materials by owners" and "lack of support from local building regulators". While the "dislike of salvaged materials by the owners" and "lack of support from local building regulators" for deconstructing buildings were ranked second and third within the "social barriers" category as well as sixth and ninth overall (Table VIII and XI), the involvement of these key stakeholders (owners and building regulators) within the implementation of RL is worth noting. One possible explanation for the lack of support from local building regulators for deconstruction could be associated with existing buildings not being designed for easy disassembly. As noted by Sassi (2004) and Kibert *et al.* (2000b), such buildings make deconstruction and RL an unenviable task due to the necessary time and labour for the disassembly of buildings. In relation to the owner's dislike of salvaged materials, as stated by Razaz (2010), reusing the products and materials of buildings is only possible if any party involved in the building life cycle is aware of the intention to reuse the products and materials after demolition or during the operation of the building.

4.4 Correlation analysis

To achieve the second objective of this study, "to establish the interaction among identified barriers to RL using correlation analysis", Pearson's correlation coefficient and the coefficient of determination were computed for the 16 barriers according to their sub-categories: the results are summarised in Tables XII-XIV.

4.4.1 Correlation analysis for operational-related barriers

The correlation analysis results for the operational barriers are presented in Table XII.

As shown on Table XII, the highest, large positive correlation ($r = 0.833$; $n = 49$; $p = 0.000 < 0.01$) was between the operational barriers 1 and 2, namely, "my firm (organisation) is reluctant to deconstruct buildings due to higher costs involved compared to demolishing" (OperBri1); and "my firm (organisation) is reluctant to deconstruct buildings because it takes a longer time to implement" (OperBri2). The relationship or association was also significant at the 0.01 level. Further examination of Table XII shows that 12 (57.14 per cent) of the total 21 correlations were significant at $p < 0.01$, whereas three (14.28 per cent) were significant at $p < 0.05$. The coefficient of determination ($0.833^2 = 0.6939$) further illustrates that 69.39 per cent of the variance in the longer time associated with implementing deconstruction of buildings can be accounted for by the level of the organisation's ability to support the higher costs associated with the deconstruction of buildings. This finding suggests that RL practices will be implemented widely only if deconstruction proves to be more cost effective compared to demolishing buildings. Nevertheless, the findings of studies have presented contradictory results in terms of comparisons between the costs of deconstruction and demolition activities.

Table XIV Results of Pearson's correlation coefficients (r) and coefficient of determination (r^2) among social-related barriers

	Coefficient of determination (r^2) or amount of variance			
Barriers[a]	**SocBri1**	**SocBri2**	**SocBri3**	**SocBri4**
SocBri1	1.000	42.77	21.16	26.32
SocBri2	**0.654****	1.000	22.27	32.72
SocBri3	**0.460****	**0.472****	1.000	28.73
SocBri4	**0.513****	**0.572****	**0.536****	1.000

Notes: Pearson's correlations among social-related barriers; where [a]SocBri = social-related barriers; **correlation is significant at ($p < 0.01$) level (2-tailed); *correlation is significant at ($p < 0.05$ level) (2-tailed); The values highlighted in bold and starred are significant at the appropriate levels, whereas the actual levels of significance though not shown within the table, is rather highlighted within the text

Table XII Results of pearson's correlation coefficients (r) and coefficient of determination (r^2) among operational-related barriers

	Coefficient of determination (r^2) or amount of variance						
Barriers[a]	**OperBri1**	**OperBri2**	**OperBri3**	**OperBri4**	**OperBri5**	**OperBri6**	**OperBri7**
OperBri1	1.000	69.39	10.24	8.58	33.18	27.46	16.97
OperBri2	**0.833****	1.000	4.12	2.22	20.88	12.32	23.91
OperBri3	**0.320***	0.203	1.000	16.81	23.91	14.59	14.36
OperBri4	**0.293***	0.149	**0.410***	1.000	38.81	16.32	2.50
OperBri5	**0.576****	**0.457****	**0.489****	**0.623****	1.000	22.85	3.76
OperBri6	**0.524****	**0.351***	**0.382****	**0.404****	**0.478****	1.000	14.36
OperBri7	**0.412****	**0.489****	**0.379****	0.158	0.194	**0.379****	1.000

Notes: Pearson's correlations among operational-related barriers; where [a]OperBr = operational-related barriers; **correlation is significant at ($p < 0.01$) level (2-tailed); *correlation is significant at ($p < 0.05$ level) (2-tailed); the values highlighted in bold and starred are significant at the appropriate levels, whereas the actual levels of significance though not shown within the table, is rather highlighted within the text

Table XIII Results of Pearson's correlation coefficients (r) and coefficient of determination (r^2) among industrial-related barriers

	Coefficient of determination (r^2) or amount of variance				
Barriers[a]	**IndsBri1**	**IndsBri2**	**IndsBri3**	**IndsBri4**	**IndsBri5**
IndsBri1	1.000	45.02	20.34	25.20	18.40
IndsBri2	**0.671****	1.000	20.97	27.56	12.11
IndsBri3	**0.451****	**0.458****	1.000	10.62	16.48
IndsBri4	**0.502****	**0.525****	**0.326***	1.000	43.96
IndsBri5	**0.429****	**0.348***	**0.406****	**0.663****	1.000

Notes: Pearson's correlations among industrial-related barriers; where [a]IndsBri = industrial-related barriers; **correlation is significant at ($p < 0.01$) level (2-tailed); *correlation is significant at ($p < 0.05$ level) (2-tailed); the values highlighted in bold and starred are significant at the appropriate levels, whereas the actual levels of significance though not shown within the table, is rather highlighted within the text

The second strongest correlation was between the organisation's decision not to support deconstruction of buildings due to the increased health and safety risks. This is because deconstruction poses higher health and safety risks (OperBri4) and requires the associated detailed planning and the need for extra effort compared to demolition (OperBri5), which was significant at the 0.01 level ($r = 0.623$; $n = 49$; $p = 0.000 < 0.01$). The inference from this result is that the organisation's support for the deconstruction of buildings should be matched by mitigation measures associated with health and safety risks, and effective detailed planning of the deconstruction process. As shown on Table XII, the weakest correlation ($r = 0.149$; $n = 49$; $p = 0.308 > 0.05$) was between the operational barriers, "my firm (organisation) is reluctant to deconstruct buildings because it takes a longer time to implement" (OperBri2) and "the organisation's decision not to support deconstruction of buildings because deconstruction poses higher health and safety risks" (OperBri4) which was also not significant ($p = 0.308 > 0.05$).

4.4.2 Correlation analysis for industrial-related barriers

Table XIII shows the results of Pearson's correlation coefficient and the coefficient of determination for industrial-related barriers.

As can be seen from the analysis, the highest, large positive correlation ($r = 0.671$; $n = 49$; $p = 0.000 < 0.01$) was between the industrial-related barriers 1 and 2, namely, "my firm (organisation) would not use salvaged materials as we cannot guarantee the quality of salvaged items" (IndsBri1) and "my firm (organisation) would not use salvaged materials as the designers do not incorporate using salvaged materials in their design proposals" (IndsBri2). The relationship or association was also significant at the 0.01 level. Further examination of Table XIII shows that eight (80.00 per cent) of the total ten correlations were significant at $p < 0.01$, whereas the remaining two (20.00 per cent) were significant at $p < 0.05$, with the coefficient of determination being $0.671^2 = 0.4502$. Thus, this further illustrates that 45.02 per cent of the variance in using salvaged materials based on guaranteeing the quality of salvaged items can be accounted for by the level of incorporation of salvaged materials in the design proposal.

These results are further reinforced and supported by the observations made by da Rocha and Sattler's (2009) study which aimed to identify the major factors which influence the reuse process. The study established and identified the variability or inconsistency of the quality of demolition products for retail as among the constraints impeding greater reuse of demolition products (da Rocha and Sattler, 2009, p. 108). The implication drawn from this result is that the quality of the salvaged items is highly dependent on the level of design which would enable the earlier dismantling of some materials and products. The study by Dowlatshahi (2000) provided some insights about the factors desirable for successful design and use of the RL systems, the underlying problem being the differing product characteristics.

4.4.3 Correlation analysis for social-related barriers

Table XIV shows the results of Pearson's correlation coefficient and the coefficient of determination for social-related barriers.

As shown on Table XIV, from the analysis, the highest, large positive correlation ($r = 0.654$; $n = 49$; $p = 0.000 < 0.01$) was between the social-related barriers 1 and 2, specifically, "my firm (organisation) would not use salvaged materials since supervisors do not like using salvaged components and materials in new buildings" (SocBri1) and "my firm (organisation) would not use salvaged materials as owners do not like to see used components and materials in their buildings" (SocBri2). The relationship or association was also significant at the 0.01 level. Further examination of Table XIV shows that all six (100 per cent) of the correlations were significant at $p < 0.01$. The coefficient of determination ($0.654^2 = 0.4277$) further illustrates that 42.77 per cent of the variance in using salvaged components and materials in new buildings can be accounted for by the level of likeability between the owners of the buildings and supervisors.

The implication to be drawn from this finding is that both owners and contractors require "social acceptance" with regards to the usage of recycled materials. Accordingly, the perception of the public in the region about the quality of recovered materials could be a make-or-break factor for implementing RL practices. This factor rests heavily on the tastes and mindsets of consumers, builders and designers in the region.

4.4.4 multivariate analysis of variance

Given that RL is closely linked to morally sensitive issues in the current socio-economic context, such as waste and environmental impact, it was anticipated that some questions in the survey (see Appendix 1) might pose ethical dilemmas for employees and managers in presenting a more reserved or biased view of those factorsTo overcome this problem, a one-way between-groups multivariate analysis of variance (MANOVA) was performed to investigate role (designation) differences in the barriers to implementing RL. The 16 dependent variables comprising the barriers to implementing RL (as listed in Table VIII) were used. The independent variables were:

- position in organisation or designation;
- length of activity in the building industry; and
- level of experience.

The most commonly employed multivariate test was that of Wilks' Lambda (Cronk, 2012), which was adopted for the current study. The distribution of respondents according to the independent variables is shown in Tables VI and VII. The results of the Wilks' Lambda MANOVA tests are shown in Table XV.

As shown on Table XV, the MANOVA showed no statistically significant difference among the various profile of respondents on the combined dependent variables: (*lambda* (80, 119.86) = 0.077, $p = 0.388 > 0.05$). The same results were observed for the respondents classified according to the "length of activity in the building industry" as follows: (*lambda* (48, 78.124) = 0.282, $p = 0.707 > 0.05$) and level of experience (*lambda* (16, 28) = 0.597, $p = 0.339 > 0.05$). In addition to the above results, other mechanisms for ensuring that the responses provided were not reserved or biased findings were compared with the existing literature, and none of the findings that emerged were contradictory to what had been reported previously.

Table XV Wilks' Lambda results of multivariate analysis of variance (MANOVA) tests

Effects	Value	F^b	Hypothesis df	Error df	Significance	Partial Eta Squared
Designation	0.077	1.057	80.000	119.86	0.388	0.402
LABI[a]	0.282	0.862	48.000	78.128	0.707	0.344
Level of experience	0.339	1.182	16.000	28.00	0.339	0.403

Notes: [a]LABI = length of activity in the building industry; [b]exact statistic

5. Implications of the findings

Some implications for practice (contractors, builders and designers), academia and research are also suggested:

- In order to address the highly ranked 'industrial-related' critical barrier associated with "limited usage of salvaged materials due to lack of design considerations" (see Tables VIII and X), this study firstly proposes that designers be more proactive in instructing clients regarding the long-term benefits of implementing the principles of RL for the design and construction of their buildings. Second, when designing buildings, due consideration should be given to the intention of maximising the use of recovered products and materials. The implication that emerges from this finding is that the benefits of implementing RL should be supported by clear metrics. As reported by Hall *et al.* (2013), this can only be achieved by developing appropriate metrics for measuring RL. Future research should conduct longitudinal studies to assess the impact of RL on a number of performance outcomes as defined by Richey *et al.* (2005a, p. 832). These include cost effectiveness; processing effectiveness; and operating level effectiveness.
- For practitioners (practice), our findings provide evidence of the "higher costs" and "implementation time" associated with opting for deconstruction. Both contractors and builders should accept the implementation of buildings that are designed based on criteria for the ease of the processes of dismantling and deconstruction at the end of the life of the building. In addition, while there is evidence in the literature acknowledging cost as an impediment to RL implementation (Carter and Ellram, 1998; Dey *et al.*, 2011; Kohn *et al.*, 2011; Huscroft *et al.*, 2013) as well as "implementation time" (Dey *et al.*, 2011), there is also evidence and justification for selecting deconstruction, such as "lower costs associated with the maintenance for the building" (Razaz, 2010), and the fact that RL also makes the construction of buildings easier (Crowther, 2001). Given the noted benefits, SA construction organisations seeking to implement RL should initially have a good financial standing as advocated by Ho *et al.* (2012). Evidence that practitioners need to see the potential of RL is further supported by the correlation analysis results, as presented in Table VI. This is through the strong positive correlation between "higher costs" and "implementation time", thus indicating a significant linear relationship between the higher correlations of the two variables.
- The second implication emerging from the "reluctance of deconstructing buildings" due to the higher costs involved suggests that in order for the "practice of deconstruction of buildings" to be adopted, there needs to be a better understanding of the issues at hand, and an increased awareness of the benefits associated with "deconstruction". As reported by Ravi and Shankar (2005, p. 1017), this "lack of awareness of benefits is a major barrier to RL". This observation indicates a need for an increased "awareness" of the benefits of RL by the relevant stakeholders, especially among the professional bodies representing contractors, salvaging companies and sub-contractors involved with RL, such as those previously identified from the population sample frame. For example, this would include members of (CCF of South Australia; Master Builders Association of South Australia; and demolition sub-contractors.
- While RL is not mandatory in SA, some lessons could be drawn from the USA. For example, design requirements geared towards easing up the requirements for dismantling and deconstruction of buildings should be incorporated in the Building Code of Australia, a remedy suggested for the USA by Chini and Buck (2014).

For academia, the present study highlights the need for integrating within their construction and project management curriculum the benefits of SCM. Similarly, for practitioners, senior management and human resource managers of construction and contracting-related organisations as well as suppliers, there is a need to invest in developing the appropriate skill levels that are desirable for implementing some of the RL practices among its employees. As noted by Aitken and Harrison (2013, p. 753), "improving the skills of operators and enhancing their competence through codification of knowledge and its formal assessment can increase the capability of the supplier". While the barrier of "personnel not possessing the skills and experience for deconstruction" was among the least ranked (Tables VIII and IX), the importance of the barrier is widely acknowledged in the RL literature (Kim and Lee, 2012).

Some implications are suggested for the government and policymakers in relation to facilitating incentives within the SA construction industry. This is particularly in response to addressing IndsBri5 (Tables VIII and X), which highlighted and linked the usage of salvaged materials to government regulation. As shown by Kibert *et al.* (2000b), the level of support coming from the government for RL is of vital importance for the regional promotion of RL practices and means the difference between success and failure. The support could be in many forms including disincentives for disposal. Similarly, seminal RL studies such as Carter and Ellram (1998); Stock (1992); and Seuring and Muller (2008) have previously acknowledged the significant influence exerted by government and regulatory bodies in RL implementation. For example, Seuring and Muller (2008) identified external pressure and incentives as being among the triggers for sustainable SCM. The major implication

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emerging from this finding, which is supported by a number of studies, suggests that the SA government should consider providing "incentives" to contractors, thereby encouraging some best RL practices. For example, this could be in the form of tax reduction and awarding incentives for builders who manage to recover high amounts of materials during the removal of buildings. To ensure compliance, as suggested by Leigh and Patterson (2006), some conditions would be attached whereby contractors would be eligible for the release of their deposit if they provide evidence of the reuse and recovery of materials.

6. Conclusions and recommendations

The purpose of this research was to investigate the perceptions of stakeholders drawn from amongst the SA construction industry contractors concerning the critical barriers to implementing theRL. This involved a triangulated data collection approach comprising a questionnaire survey among construction stakeholders in SA and a literature review. The findings from the quantitative part of the study (Table VIII) showed that the top highly ranked critical barriers were drawn from the "industrial category", namely, "lack of incorporation of salvaged materials by designers" and "regulation restrictions to usage of recovered materials and components". This was followed by the social-related barriers of "potential legal liabilities and adverse consequences" and the two operational-related barriers of "higher costs" and "longer time associated with deconstructing buildings".

Correlation analysis (Tables XII-XIV) of the critical barriers within the different sub-groupings demonstrated that apart from the minority (19.04 per cent) among the critical barriers within the "operational" category where the strengths of relationships were within the small and positive (r = 0.10 to 0.29) range as classified by Cohen (1988, cited in Pallant, 2005), the remainder of the strengths of relationships across the three groupings were classified as medium and positive (r = 0.30 to 0.49) followed by the large grouping (r = 0.50 to 1.0).

Based on the findings from the questionnaire survey and augmented by the review of the literature, the following recommendations emerge with these associated with design, cost and quality issues; cultural awareness; and others mostly drawn from the strategic management discipline and principles:

6.1 Consideration of design, cost and quality issues

While the study categorised the barriers to RL used in the survey into operational, industrial and social, some common threads emerged across these three categories. One such thread relates to design issues as was evident in OperBri3 and IndsBri2. The issue of cost was also clear in OperBri1 and IndsBri3, whereas the role regulations were evident in IndsBri4 and SocBri3. While it is beyond the scope of this paper to articulate all the solutions to the identified barriers, the following quality-related issues are worth stating:

Among the major impediments to RL identified in the RL literature were guaranteeing the "quality of salvaged items", "design issues" and "higher costs". Against that background, researchers in the construction field have regarded information exchange as central to effective SCM for construction projects (Bankvall *et al.*, 2010; Love *et al.*, 2004; Pun *et al.*, 2005; Richey *et al.*, 2005b). Therefore, it is firstly recommended that SA construction organisations and associated stakeholders seek to enhance this exchange of information. Further evidence of the practicability of this approach is provided by Pun *et al.* (2005) who note that the exchange of information plays a vital role in enhancing cooperation between key players of the RL system including owners, deconstruction contractors, the new building project team and potential demanders of salvaged materials. This would reduce the costs of transportation (i.e. OperBri1) and inventory, and prevent losses of time in this process (i.e. OperBri2). Furthermore, studies such as the work of Kim and Lee (2012) have demonstrated that stakeholders can have a huge impact on companies' decisions about strategies by providing regulatory schemes.

Second, in addressing the design issues (OperBri3 and IndsBri2), designers should take note that despite the opportunities provided by building materials and products (e.g. bricks), such as the possibility of using them in different buildings many times, this appears to be highly dependent on the design of a building and its construction methods.

6.1.1 Cultural issues and increased awareness of RL benefits

The descriptive statistics associated with the "social barriers" (Tables VIII and XI) and the results of the correlation analysis indicate that there is a need to educate key stakeholders, such as owners and building regulators, in addition to contracting organisations, about the perceived benefits of RL. Drawing upon the approach and suggestions by Chileshe and Kikwasi (2014) and Chileshe and Yirenkyi-Fianko (2011), albeit within the realm of risk assessment and management practices, one such recourse would be the undertaking of an awareness campaign by relevant stakeholders, including the government in the context of South Australia. This approach could involve the introduction of training programmes associated with RL as well as focussing on mechanisms (such as workshops and seminars) that are aimed at sensitising their members to the benefits of RL implementation. SA construction organisations could further draw on lessons from Ojha *et al.*'s (2013, p. 200) study which advocated for an enabling environment where employees could act proactively, without fear of reprisals when mistakes occur. This is only possible with good policies which have this as their aim.

6.2 Application of strategic change approaches to managing RL barriers

It is recommended that the SA construction organisations should embed and adapt some of the activities inherent in managing strategic change, as advocated by Balogun (2001) and Johnson *et al.* (2008). This entails understanding the transition curve in order for individuals to experience change (Balogun, 2001, p. 9). For example, Table XI showed that organisations were reluctant to use salvaged materials (SocBri1). This highlights the need for transformational change initiatives such as improved communication, and education and training on the benefits of using salvaged materials. Using the transition curve proposed by Balogun (2001), this "acceptance" of salvaged materials would only follow after the "awareness" stage. As demonstrated by Ravi and Shankar (2005, p. 1017), the lack of awareness of the direct benefits to the environment from the implementation of RL can act as a major barrier to RL.

6.3 Application of strategic planning approaches to managing RL barriers

To identify the forces or barriers facilitating or blocking the changes associated with adopting some RL practices (such as usage of salvaged materials), it is recommended that the SA construction organisations should undertake a forcefield analysis. For example, as illustrated in Tables VIII and X, the highest ranked barrier overall was the "industrial-related" "my firm would not use salvaged materials as the overall costs of salvaged material is higher than using virgin products" highlighting the need for change towards the usage of salvaged materials. Drawing upon the discipline of strategic management, Johnson *et al.* (2008, p. 505) state that a forcefield analysis can provide an initial view of the problems that need to be tackled by building on the forces that might work for change and reducing the forces against change. Similarly, in dealing with the highest ranked barrier within the "operational" category, namely, "my firm is reluctant to deconstruct buildings due to the higher costs involved compared to demolishing", the role of strategic management and associated decision-making principles is further evident in the RL literature. For example, Hazen *et al.* (2012, p. 256) identified "costs" as one of the seven key components which may affect a firm's decision as to which RL disposition activity to employ. The remaining six components were as follows:

1 customer behaviour;
2 environmental impact;
3 market conditions;
4 supply chain capabilities;
5 regulations; and
6 profits from RL.

Therefore, the SA construction organisations are encouraged to integrate and include costs among the primary considerations prior to adopting some of the RL practices. This consideration can and is normally undertaken as part of strategic planning when organisations decide which businesses and markets in which to compete. Similarly, some of the seminal studies in RL such as Autry (2005) have suggested that managers should align RL policies with strategic goals.

Accordingly, undertaking strategic planning would enhance the achievement of and contribution towards two (out of eight) of the desirable steps advocated by Hazen *et al.* (2012) as necessary for RL disposition decision-making. These two identified steps are as follows: scan the external environment; and scan the internal corporate environment. The importance of strategic planning is further acknowledged in the literature (Ravi and Shankar, 2005; Mitra, 2007; Hosseini *et al.*, 2014). For example, Ravi and Shankar (2005) state that to achieve the goal of the organisation's survival in the global market, strategic planning should complement RL implementation. The same study by Ravi and Shankar (2005, p. 1,016) acknowledges that while the training of personnel related to RL might be important for successful implementation of RL and for making the process "profitable", costs would still need to be incurred. Mitra (2007) also notes that strategic cost management decisions regarding RL implementation are central to its success, whereas Hosseini *et al.* (2014) acknowledges that the internal barriers to RL implementation are within the strategic management decision-making system. Furthermore, it should be acknowledged that some of the seminal studies within the field of RL such as Gardner and Cooper (2003) also advocated the usage of "strategic supply chain mapping" as a mechanism for linking the strategic planning process of the firm to facilitate the evaluation of the supply chain membership and structure (Gardner and Cooper, 2003, p. 37). This mapping exercise could be undertaken during scanning of the "internal" and "external" environment as previously identified.

6.4 Limitations

While the study makes several contributions to the SCM and RL theory and practice, some limitations should be noted. The first limitation relates to the cross-sectional nature of the quantitative study which only captures the perceptions of respondents at a point in time. The further limitation associated with these types of study of the complex and under-researched area of RL is the inability to capture the viewpoints of multiple actors over time. One suggested solution to overcoming this limitation is employing longitudinal studies. As indicated by Richey *et al.* (2005a, p. 838), this temporal perspective would allow for a deeper understanding of RL implementation barriers. Notwithstanding this limitation, the reported results from the quantitative study appear to be consistent with previous research examining the implementation issues and barriers to RL.

The second limitation relates to the population sample being restricted to only South Australia and the construction industry; therefore, the generalisation of the findings to other industries might not be possible. As observed by Autry *et al.* (2001, p. 31), the type of industry has significant implications for the level of satisfaction with RL service; hence, the barriers might also be different. Future studies should be extended to other industries such as manufacturing and services. The final and third limitation relates to the small sample size ($n = 49$) for the survey. This limited the application of rigorous techniques such as structural equation modelling and interpretive structural modelling methodology which would have further tested the interactive effects of the barriers, as well as some of the identified propositions in the existing models and frameworks. However, despite the small sample size which is highly focussed on small to medium-sized contractors (see Table VII), the study does provide a snapshot of the current barriers (see Tables I-III and Table VIII) inhibiting or impeding the implementation of RL and the interactive effects (see Tables XII-XIV) between different pairs of variables in relation to RL barriers. Given the scarcity of empirical research on RL within the SA construction context, this study contributes to the theory building within that area and further extends and builds upon the works of Carter and Ellram (1998). This is achieved through the empirical testing of selected propositions on the relationships between the different RL barriers and the correlation and ranking analysis (Tables XII-XIV). Against that background, caution should be exercised in the interpretation and generalisation of the results. Future studies should employ larger samples, as has been previously acknowledged in RL-related studies such as the work of Richey *et al.* (2005a).

The other recommended technique is the Delphi study which could be conducted among SA practitioners (including designers) regarding barriers to implementing RL. This approach, in addition to providing insights on barriers to implementing RL, is also identified as a valid approach for uncovering the most important issues facing today's RL practitioners (Huscroft *et al.*, 2013, p. 306). In addition, the Delphi method has been recommended as an appropriate tool for research in strategic management (McDermott and Stock, 1980; Loo, 2002). Investigating the barriers to RL implementation using this technique would be of benefit particularly when expecting conflicting policy directions.

The third limitation is associated with the skewness of the sample strata: examination of Table VI shows that designers were not among those surveyed. This omission might have an impact on the higher ranking assigned to IndsBri2 that is associated with the organisation's inability to use salvaged materials due to the lack of incorporation of the use of salvaged materials in their design proposals. Although this might be constructed as other stakeholders (respondents) appearing to "blame" designers, there is evidence from the literature (Gorgolewski, 2008; Crowther, 2009; Densley Tingley and Davison, 2012) that has identified the lack of attention to design for RL as one of the major barriers to RL implementation. A separate study in the form of interviews undertaken as part of this project further highlighted the lack of knowledge about RL in the SA construction industry. This further reiterated the lack of commitment from designers and consultants to giving consideration to instructing their clients and contractors regarding the vital aspects of RL in construction projects. Notwithstanding the noted support, future studies should include designers among those surveyed to confirm or refute the observations as claimed.

In addition, by undertaking a triangulated approach through the Delphi method, interviews and a questionnaire survey within one study would enable the validation of the results. Ojha *et al.* (2013) used a similar approach in a study that sought to extend existing theory by examining the impact of logistical business continuity planning on the organisation's operational and financial performance. In addition to including designers and other stakeholders, future research should attempt to differentiate the perceptions of the barriers to implementing RL across the different groupings, as each group might have different interpretations of what constitutes a barrier to implementing RL. Furthermore, this kind of study would deepen our understanding of whether there is a general consensus among stakeholders regarding the barriers, and would open avenues for the development of different "RL mapping" exercises which could be attributed to different stakeholders. As pointed out by Gardner and Cooper (2003, p. 39), "these maps have the potential of cataloguing different kinds of information required for survival in a dynamic environment". The construction industry is one such turbulent environment.

The other area of future research is in response to RL barrier, IndsBri1, which is associated with the "lack of guarantee of the quality of salvaged items". While the idea might appear far-fetched, there is nevertheless the need to explore the development of a "RL-self assessment and rating tool" whose aim would be focussed on the assessment and classification of used products according to their quality condition. In a view supported by Liao-Troth *et al.* (2012, p. 24), "researchers also have the opportunity to 'look ahead' and anticipate topics that may be important before catastrophic events have occurred". Conversely, this proposed future research is similar to and aligns with some of the future directions in RL suggested by Huscroft *et al.* (2013, p. 318) such as the "establishment of metrics to monitor the degree to which processes meet standards".

Second, in the quest to advance and contribute to the research agenda in the areas of SCM and RL, future research could be further aimed at exploring the synergies between RL and the existing multidisciplinary themes within the natural and built environments and SCM.

Finally, this empirical study is undertaken within a single industry, construction. Therefore, the results may not be generalisable to other contexts. However, despite this shortcoming, the majority of the literature reviewed was from other industries, particularly the studies undertaken by Hosseini *et al.* (2013, 2014).

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Appendix 1. Extract of questionnaire on reverse logistics (RL) barriers

Figure AI

Section 4: Barriers to implementing reverse logistics (RL) in building projects

Please indicate your firm's level of agreement with the statements provided regarding the barriers to implementing reverse logistics (RL) in building projects. Please read each statement carefully and tick (☑) the appropriate box (Key: SA = strongly agree (SA); A = Agree; N = Neutral neither (Neither Agree nor Disagree); D = Disagree; and SD = strongly disagree.

Label	Reverse logistics barrier	SA	A	N	D	SD
OperBri1	My firm is reluctant to deconstruct buildings due to the higher costs involved compared to demolishing	☐	☐	☐	☐	☐
OperBri2	My firm is reluctant to deconstruct buildings because it takes a longer time to implement	☐	☐	☐	☐	☐
OperBri3	My firm would not support deconstructing buildings because existing buildings are not designed to be deconstructed	☐	☐	☐	☐	☐
OperBri4	My firm would not support deconstructing buildings because deconstruction poses higher health and safety risks	☐	☐	☐	☐	☐
OperBri5	My firm would not deconstruct buildings because deconstruction takes detailed planning and needs extra effort compared to demolition	☐	☐	☐	☐	☐
OperBri6	My firm would not deconstruct buildings because the personnel do not possess the skills and experience for deconstruction	☐	☐	☐	☐	☐
OperBri7	My firm would not be supportive of using salvaged materials and components as we could not be confident of the availability of required materials and products on time	☐	☐	☐	☐	☐
IndsBri1	My firm would not use salvaged materials as we cannot guarantee the quality of salvaged items	☐	☐	☐	☐	☐
IndsBri2	My firm would not use salvaged materials as the designers do not incorporate using salvaged materials in their designs proposals	☐	☐	☐	☐	☐
IndsBri3	My firm would not use salvaged materials as the overall costs of salvaged material is higher than using virgin products	☐	☐	☐	☐	☐
IndsBri4	My firm would not use salvaged materials as culture and perceptions governing the building industry oppose using salvaged components and materials	☐	☐	☐	☐	☐
IndsBri5	My firm would not use salvaged materials as regulations confine the use of recovered materials and components in building projects	☐	☐	☐	☐	☐
SocBri1	My firm would not use salvaged materials since supervisors do not like using salvaged components and materials in new buildings	☐	☐	☐	☐	☐
SocBri2	My firm would not use salvaged materials as owners do not like to see used components and materials in their buildings	☐	☐	☐	☐	☐
SocBri3	My firm would not deconstruct buildings as local building regulators do not support deconstructing buildings instead of demolition	☐	☐	☐	☐	☐
SocBri4	My firm would not use salvaged materials due to potential legal liabilities and adverse consequences	☐	☐	☐	☐	☐

Notes: OperBri = Operational-related barriers; IndsBri = industrial-related barriers; SocBri = social-relatedbarriers

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