Data quality as an antecedent for commercial viability of circular economy business models: a case study

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Abstract

Introduction - The aim of this paper is to explore data quality as an antecedent of commercially viable business models within the circular economy. Australian state governments are developing policies to enable a circular economy. However, in the building industry most data systems rely on self-reporting, which has compromised the accuracy, objectivity, transparency and integrity of data reported on raw materials within components and products.

Method - This paper uses a case study to demonstrate how digital data systems that independently track, trace and verify the provenance of inputs of raw materials, components and products, can accurately inform the value of circularity in the built environment. Interviews were conducted with an office furniture supplier who developed a digital system to inform circularity. Also interviewed was a sustainability consultant who assisted, and has since prototyped a digital system designed to accurately enable circular value to be identified in the built environment. Feedback on the design and prototype of this proposed system was provided by building industry value-chain stakeholders through a series of seminars and design thinking workshops.

Results - Commercial viability of a circular economy model was reliant on a framework of data quality that recorded raw materials, traceability and verification to establish trust: 1) data capturing raw materials within components of products (e.g. metals, melamine and plastics), 2) data tracking of products throughout their life-cycle, and 3) data verifying the authenticity of raw materials and products. This framework of data quality was critical to delivering circularity outcomes for reuse of products, repurposing components, recycling and minimising landfill.

Conclusion - This study proposes that data quality is integral to the commercial viability of circular economy business models in the built environment. Data quality in a circular economy means having the digital capability to objectively track, trace and verify the integrity and composition of building materials, products and assemblies throughout their lifecycle.

1. Introduction

The concept of Circular Economy (CE), which has gained increasing attention in Europe is also gaining recognition in Australia. Various state governments (e.g. Victoria, NSW and Queensland) have recently issued policies or discussions papers on circular economy for their own jurisdictions. However, the transition towards a CE has proven more challenging [1]. Within the building industry the presence of viable CE business models (BM) is limited. While digital technologies promise potential for product-service model businesses [2], the building industry in Australia provides few examples. Egans - Wise Office Furniture, provides an ideal case study, as they have managed to overcome some of the challenges of transitioning to a CE, by designing a framework of data quality as an enabler, in developing a product service system (PSS) [1]. Importantly, they credit the design of their digital data quality framework for...
enabling a desirable, feasible and viable CE business model. Despite receiving limited attention [3, 4] there is growing interest in how digital data technologies (e.g., Internet of Things, big data and blockchain) may be used to overcome the complexity of challenges CE imposes [5].

This paper addresses this gap by exploring how businesses in the building industry can transition to CE models, using digital data technologies. To narrow the scope this paper focuses on establishing a framework of data quality, based on key insights from the Egans case study. We were fortunate to have unusual access to this case as one of the authors began consulting with the company in 2012. The consultant co-designed Egans asset management system to incorporate CE practices as informed by the Australian Government’s Product Stewardship Act (2011) [6]. The Act presents a framework “to reduce the impact that products have on the environment, throughout their lives; and that substances contained in products have on the environment, and on the health and safety of human beings, throughout the lives of those products” [6]. Egans co-created a product stewardship scheme (CE value proposition) in alignment with The Act [6], which has proven desirable to customers and the company, as they receive reporting on the environmental impact of furniture supplied (e.g., quantifying their contribution to landfill reduction). Subsequently Egans has become a niche market leader with their CE PSS BM and has thrived commercially, particularly with institutional customers.

2. Background

Using a PSS BM as a case study is useful as these provider businesses assume the risk of product ownership, imposing upon themselves the responsibility for delivering product provenance; delivering agreed performance [7] and value [8] to customers. This creates an incentive to ensure the PSS BM is designed to mitigate risks and to ensure that CE value is optimised in products and materials that they procure [7]. Having accurate and reliable knowledge of the value of waste so CE potential of products and materials becomes an imperative for CE PSS BMs to be viable. The question to address is: How to design a digital data system that mitigates risks and optimises value?

Research into the design of digital systems to capture relevant data, important to the knowledge requirements for CE, is evolving in the building industry [5]. This research encompasses tools designed to record the composition of building products (e.g., materials passports and BAMB), modelling and documentation tools to improve the management of planning, design, build, operations, maintenance and recovery (e.g., Building Information Modelling (BIM)), as well as track-and-trace tools designed to record movement of products throughout the supply chain to enable circular recovery (e.g., SmartTrack). This evolving area of research promises to inform solutions for the feasibility of CE within the built environment. However, unrecorded product substitution, often non-compliant with the building codes, appears to be widespread and significant across the industry globally [9]. This product substitution contaminates data quality and thus needs to be designed into a framework for data quality.

Submissions and findings of both an Australian Government Senate Enquiry into non-conforming products in the building industry [9] and the Victorian Cladding Taskforce [10] that investigated how inferior and unsafe cladding products have permeated the industry, provided important findings. Non-conforming and regulatory non-compliant product substitution is driven by a number of reasons. From a systems perspective, these can be categorised [11] as cost-driven inferior and/or illegal product substitution, absence of reliable verification of product certification, unverifiable product labelling, unreliable or non-existent site inspections, building performance and longevity is compromised, inability to identify, attribute and penalise fraud.

Self-reporting of data, without independent verification emerged as a major problem including self-reporting of product data that enters into commonly adopted systems such as BIM and other track and trace tools. It is evident that while product categories in other industries have embraced digital technologies to ensure the provenance of products (e.g., food and pharmaceuticals), the building industry has yet to embrace such technologies. For example, the Australian beef industry has adopted technology developed by PricewaterhouseCoopers (PwC) which uses nano-scale silicon dioxide particles sprayed onto meat as it is packed in Australia. Scanning products at point-of-sale enables real-time data matching
to ensure the products authenticity and supply chain history, including unique National Livestock Identification System tag numbers appropriated to livestock on Australian farms [12].

3. Construction industry and digitisation

The global construction industry needs to digitise for economic and environmental optimisation [18, 19, 20, 21]. It is forecast to grow to US $12.7 trillion by 2022 [13], it consumes half of all non-renewable resources [14] and it causes one-third of all waste to landfill globally [15, 16, 17]. McKinsey Global Institute estimates US $1.6 trillion can be gained with digitisation [23]. Building Information Modelling (BIM) is a tool to communicate data such as geometry, quantities, cost-estimates, project-schedule and performance for designing, procurement, fabrication, construction, operation, maintenance and deconstruction. BIM also creates quality control [24, 25], tracking warranty and service information [27]. As BIM encompasses the entire building lifecycle [27], it can be used to extend the lifetime of the building and its elements. However, BIM does not enable objective independent verification of the quality of data entered [26, 28]. It cannot account for poor quality, and the use of non-conforming and non-compliant products, materials and assemblies entering the built environment [22, 30].

Quality control and trust can be controlled with Distributed Ledger Technologies (DLT) known as Blockchain 2.0. DLT can be defined as a verification tool for transaction and programmable distributed trust infrastructure [31]. However, challenges exist including a lack of trust, regulations and precedents as well as coding, executing and enforcing smart contracts [32]. Furthermore, it would still be possible to fraud the data of building elements [29, 33]. Designing digital systems with a trusted framework of data quality has proven elusive [34, 35]. Enabling objective, independent verification of product and material authenticity for satisfying building code standards and regulatory compliance, is absent from known digital systems.

After co-designing improvements on Egans CE PSS BM, a digital data platform suited for the challenges encountered in the building industry was conceived. This CE platform was designed to be a cloud-based system, that interacts with BIM, using the capability of DLT designed to enable holistic tracking of products throughout a CE. This digital platform was designed to address verification and traceability of building elements, and rank organisations on trustworthiness. Conceptually, it could be programmed into a DLT software like Ethereum, NEO or Brickschain, which are emerging software to offer DLT for the building industry [36].

4. Methodology

Given, the paucity of viable circular economy models in the building industry in Australia, we chose the case of Egans [38] that has evolved a viable model for circularity predicated on a framework of data quality that they identified. The case is illustrative in nature and builds on various sources. A research grant funded capturing a short video [40] of the case study, with the founder as a co-storyteller, which demonstrates the inductive analysis of data, and aids communication and impact. Information about the company, its process and practices and discussions with Egans sustainability consultant were also undertaken to support in triangulation of data [39]. A single case is justified where it provides innovation, unique access and is unusually revelatory [41, 37]. Further, interviews with Egans sustainability consultant, and a co-author, articulated important learnings from co-designing their data quality framework and provided unusual access to this case [42]. A data quality framework and a digital prototype incorporating a range of integrated technologies was designed for the purpose of experimentation and gaining feedback via a series of forums and design thinking workshops involving industry value-chain stakeholders. They included builders, sub-constructors, manufacturers, suppliers, maintenance, insurance, unions, government departments and industry associations (trade and manufacturers). The multiple inputs helped create an understanding of the main themes of concern regarding data quality, including multiple viewpoints from those closely involved. This informed the research question: What framework of data quality enables viable CE BMs in the building industry?

5 Results
5.1. Case study - Egans
Egans was founded in 1996 in Australia as a furniture removal company, making business from reverse logistics. Over time their business model changed, in response to changes in furniture composition and quality. Originally a good margin was made with redistributing traditional furniture (e.g. wooden) and the emerging potential for refurbishing newer system furniture. Around 2000 an increasing supply of low-cost-low-quality furniture saturated the market. This reduced the market interest for used furniture. It also diminished end-of-use value of this low-quality furniture. Recycling materials became the main remaining value, sometimes solely to avoid a government-imposed landfill levy.

In 2012, Egans, with the aid of a sustainability consultant, co-designed a product stewardship system incorporating track-and-trace technology and lifecycle-data technology to effectively assess the potential for reuse, refurbish or recycling of office furniture, as per the Ellen MacArthur model of CE [43]. Incorporating a framework supported by the Product Stewardship Act (2011) [8], a CE value proposition was created as an incentive to encourage customers to engage Egans as their preferred product service provider. Customers would gain independent reporting on their contribution to the environment, by quantifying landfill reduction enabled by CE. The Act provides a whole of lifecycle approach. Egans PSS was able to report on end-of-life management of assets at a product level, drawing on knowledge captured over approximately 20 years of operation. Egans now has several years of quality data that enable it to report to customers on the lifecycle of its furniture. Egans identified value in documenting circular economy outcomes and selling the information as a report to those organisations paying for disposal of assets, providing them verifiable land fill avoidance reporting. This provides Egans with competitive advantage in a niche market, slow to transition to CE business models.

Beyond 2012, co-design of Egans CE PSS BM continued for systems optimisation. This smart data management capability increased margins and profits where the market-standard alternative was paying disposal and landfill fees. The design of the system enabled Egans to maintain proprietary CE data matching capability, using their own historical longitudinal data set, to ensure CE value was delivered.

Egans business model is economically effective, socially responsible and reduces environmental impact. This model demonstrates how a circular economy can capture value throughout the product lifecycle. This in turn provides an economic rationale at procurement, the decision-making time, for sustainable product preference. Today the business employs 120 staff, owns 22 trucks and enjoys a niche market position in offering circular value to its customers. Their small market share consists of mostly institutional customers and socially responsible organisations.

5.2. Learnings and limitations from Egans Case Study
Learnings from the Egans case study informing a framework for data quality within a PSS business model include:

1. Data on products and material needs to be obtained to inform CE procurement decisions
2. Data matching with a database of known CE values is required
3. Track and trace capability are required throughout the product lifecycle.

Limitations of the Egans framework of data quality include:

1. Reliance on historical longitudinal data on products and materials
2. Lack of independent, objective third-party verification of product data matching
3. Limited scalability and transferability to businesses in other product markets.

5.3. Addressing the problem of scalability for the building industry
Translating the Egans BM to new businesses, presented a challenge, as Egans data matching relied on having many years of CE product data, which was incorporated into their redesigned PSS. A problem remained; how to design a system that would be viable for a new business where no tried and tested experience of CE value could inform developing a database?

Egans sustainability consultant since attempted to solve this problem for the building industry. A prototype CE BM was designed, informed by learnings from the co-design of Egans CE PSS BM and prior involvement in product procurement, placement and reporting within the Defence Industry, where
systems have been designed to mitigate risks attached to product authenticity. The consultant was familiar with extant issues in the building industry having managed and consulted on numerous projects. Subsequently, a framework of data quality for the building industry was designed.

5.4 Proposed framework of data quality for Building Industry

The proposed data quality framework is modified from the Egan’s data system and framework to account for its limitations and to enable suitability for complexities in the building industry.

Proposed data system and quality framework incorporate:

1. A unique product code is required on materials, products and assemblies
2. Mandatory fraud resistant labelling is required on materials, products and assemblies
3. Mobile scanning capability is required for real-time, independent, data matching to ensure product authenticity, supply chain history, verify certified claims of conforming to industry standards, and to demonstrate compliance with jurisdictional regulation.
4. Real time traceability and active verification of waste and value opportunities at raw material, product and assembly level.
5. Integration with BIM, in the form of an industry standard system used by major constructors.
6. Variety of standardised application protocol interfaces allowing consistency in open collaboration.
7. Standardisation of lowest common denominator metrics.
8. Track and trace technology to enable accurate location within the built environment.
9. A product and business entity maturity framework allowing ratings and metrics to be defined and further developed
10. A rating system (e.g. traffic light system), to identify the status of products according to the standards, and regulation they are matched against.

Several design thinking workshops were conducted involving value-chain stakeholders at all stages of produce lifecycle from cradle to grave. Emergent themes revealed that a key problem is that tenders base their valuation of buildings at the beginning of their life (upon completion), rather than whole of life. This places project completion costs as the means to complete successfully for tenders. This results in financial pressures borne throughout the value-chain to project delivery and warranty period. Subcontractors, typically are small to medium sized businesses with limited bargaining influence in the value-chain, and while large multi-national construction companies compete on cost for projects, they often maximise their margins by placing cost pressures on subcontractors, who then view product substitution as the most effective means of maximising their own profit margins. Remote manufacturers and suppliers thrive under the current system, which enables self-reporting of data, the absence of independent third-party verification of claims made by products (manufacturers and suppliers), and incentives for building inspectors to report favourably to constructors who they rely upon for ongoing contractual employment. Independent inspection services provided by industry bodies are insufficient in number for the industry, and many products cannot be identified as non-conforming to regional standards or non-compliant with jurisdictional regulations as was found by the Victorian Government Funded Cladding Taskforce (2017) [10].

Feedback on the proposed data system and quality framework identified by industry stakeholders include:

1. Transparency problems associated with poor installation of products.
2. Challenges associated with placing undetectable labelling on materials (e.g. steel).
3. Willingness of building constructors to expose themselves to transparency, due to risks of existing exposure to litigation.
4. Integration with existing systems, as proposed, would overcome resistance to adoption.
Collective understanding emerged among building industry stakeholders that viability of a CE BM was reliant on a framework of data quality that recorded raw materials, traceability and verification to establish trust: 1) data capturing raw materials within components of products, 2) data tracking of products throughout their life-cycle, and 3) data verifying the authenticity of raw materials, products and assemblies including their conformity to, or deviation from, industry standards and compliance with jurisdictional regulation. Identifying a framework of data quality that meets the needs of the building industry was found to be critical to enabling CE BM’s and delivering CE outcomes including, reuse of products, repurposing components, recycling and minimizing landfill.

6 Discussion and conclusion

This story of business innovation forced by changing design, inspired by business values and now influencing consumer behaviours, provides insights to future business models that prepare us for circular economies and capturing value throughout the product lifecycle. By referencing data at a product level, captured over two decades Egans demonstrate trends in the market that have first seen the collapse of the traditional secondhand market leading to the emergence of socially responsible procurement, resale, reuse and material recovery at a product function end-of-life. This provides an economic rationale at procurement decision making for sustainable product preference in the presence of higher capital expenditure with the knowledge of, and ability to capture value from, higher utilisation, productivity, employee wellbeing and lower operating cost.

Feedback from building industry stakeholders on a modified data system and data quality framework proposed for the building industry, informed both the desires and concerns of the industry. These insights will help guide the design and innovation of suitable systems designed to enable transitioning of the building industry towards CE BMs. Having unusual access to this revelatory case study shines a light on the need for innovation to co-create with industry, to ensure the desires and concerns of relevant stakeholders inform the innovation process and open areas of collaboration for a true CE.

This research demonstrates that data quality and stakeholder attribution correlation is integral to the commercial viability of businesses that operate under a circular economy model. It is necessary to have the digital capability to independently verify the integrity and composition of building materials using a holistic digital system that matches data, tracks and traces products throughout their lifecycle. Industry stakeholders confirmed a view that integration with existing technologies such as BIM was desirable. However, concerns of exposure to litigation undermine embracing DLT technologies, such as Blockchain, particularly among builders.

Limitations of this study include the use of a case study that adopts a CE PSS BM, while other business models were not considered. Future research suggestions include testing the proposed data quality framework on a live industry project within the building industry to measure CE value for stakeholders.

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