Organic Compost Supply Chain Analysis in Regional South Australia

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Executive Summary

The Central Local Government Region of South Australia (trading as the Legatus Group) was commissioned by the SA Regional Organisation of Councils (SAROC) and secured funding from Green Industries SA to assess the potential viability of processing regional waste in the regions. This has created two reports: Waste Management Infrastructure for South Australian Regional Local Government, and Regional SA Waste and Resource Recovery Background Report by Rawtec. These reports indicate that composting facilities in regional South Australia might be viable. The plant/s would process organic material collected by Councils and produced by industry and its output could be used by agricultural industries or other markets in regional SA.

This study builds on that previous work to generate insights into the contractual and logistical challenges along the supply chain connecting regional organic material sources with regional organic compost processors and users.

For the study, we employed two analytical approaches: Supply Chain Analysis (SCA) and Transaction Costs of Economics (TCE). These two elements guided the qualitative, semi-structured interviews of suppliers, processors, and end-users to generate insights into the potential organic compost supply chain.

The research outcomes are summarised below:

1. Raw organic material is currently repurposed rather than discarded and is therefore not waste per se. But current uses are simple and low cost, meaning also that they are low value uses.

2. Regarding regional sources of organics, their logistical challenges appear to be minor and thus, transaction costs are unlikely to be a significant impediment to suppliers' involvement.

3. In terms of processing, a small regional plant is not capital intensive, especially using mobile, shared equipment. However, contamination of both inputs and outputs has been identified as a critical issue and falls within the activities of the processor. Processors face high transaction costs, especially in monitoring the process in line with the specifications of each region’s user requirement and managing the consequences of failing to eliminate contamination. Reducing these transaction costs by addressing

the logistical challenges is expected to boost the development of these supply chains significantly.

4. Farmers are the most common regional users of organic compost. Current arrangements, using mostly synthetic fertilisers, are problematic and a source of high transaction costs. But transaction costs are also likely to be high using regionally sourced organics as farmers incur costs to govern the consistent supply they need in terms of both quantity and quality characteristics. Switching to organic compost will be a major change for many agricultural farmers with high transaction costs, particularly the expected costs of failure. The challenges facing users also constitute a significant impediment to the emergence of the proposed organic compost.

5. Finally, and more generally, there are almost no regional organisations that might help address the challenges. Instead, interviewees tend to make use of their close relationships and informal processes to enforce specifications if there are failures.

The study, therefore, revealed that, while organic waste processing appears to be viable for organic compost, the costs of organising its supply chain might be prohibitively high. Building more processing plants is unlikely in the absence of additional initiatives.

Two kinds of initiatives are contemplated. Firstly, it will be helpful to develop industry organisations that can operate effectively along the supply chain and at a regional level. Consideration could be given to institutional forms such as regional composting cooperatives or Councils forming a Regional Organic Waste Authority. Secondly, targeted assistance could address the key challenges that have been identified in this study. There is a need to develop cost-effective and trusted means of monitoring inputs and outputs. There is also a need to provide information and training to reduce the uncertainties of participating.

SECTION 1

1 Introduction

1.1 Project background

This project on supply chain analysis of organic compost is a subset of a larger on-going project. The South Australian Regional Organisation of Councils (SAROC) commissioned the Central Local Government Region of South Australia (trading as the Legatus Group) and secured funding from Green Industries SA to undertake preliminary work and produced two reports: Waste Management Infrastructure for South Australian Regional Local Government; and Regional SA Waste and Resource Recovery Background Report by Rawtec. These reports indicate that composting facilities in regional South Australia may be viable.

The Legatus Group comprises fifteen councils in regional South Australia (Figure 1). Councils own and operate systems for the collection and management of waste for a number of communities and these are a source of organic materials. From a supply chain perspective, the study has investigated the contractual difficulties that give rise to challenges along the supply chain. It has sought to establish why these facilities have not emerged, given the preliminary analysis that they are viable. This work has been aimed at generating insights into the contractual and logistical challenges along the supply chain connecting regional organic material sources with regional organic compost processors and users.

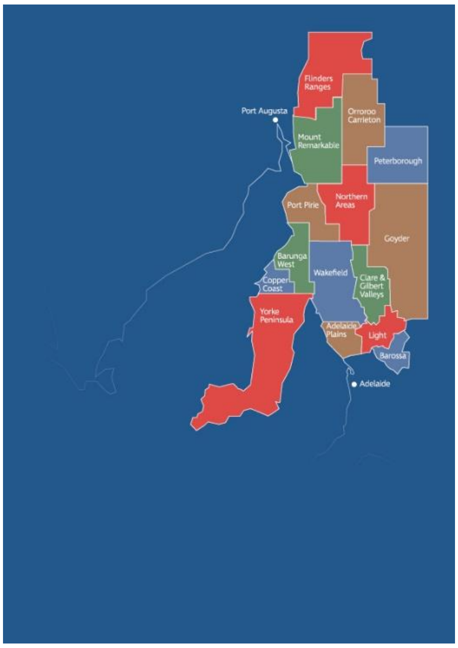

Figure 1: Map Legatus Group Councils

1.2 Aims and scope of project

The objectives of this project are:

- To investigate and understand investments by stakeholders dedicated to participating in the organic compost processing supply chain.
- To provide an assessment of the variability of sources of supply and levels of demand.
- To identify sources of high transaction costs along the supply chain and provide solutions to reduce those transaction costs.

To meet those objectives, this work has made use of the academic literature of Supply Chain Analysis (SCA) and Transaction Cost Economics (TCE). These concepts are discussed in section 3 below but, by way of introduction, the literature leads to the following research questions.

- What assets are needed to participate in the supply chain for organic compost processing?
  - ✓ By suppliers of organic waste, processors, and users of organic compost
  - ✓ The focus is on investments that are dedicated to this purpose and not easily repurposed
- How variable are the supply of organic waste and demand for organic compost?
  - ✓ Both quality and quantity
  - ✓ Why are these inconsistent?
- What are the contractual difficulties that give rise to high transaction costs? Why is it difficult to
  - ✓ Specify the terms of agreements along the supply chain
  - ✓ Monitor performance of the parties
  - ✓ Enforce the terms of those agreements?
- What solutions are available?
  - ✓ Contracts and relationships between stakeholders along the chain
  - ✓ Institutional arrangements among stakeholders.

1.3 Project research methodology

The project undertook interviews with senior managers and owners of Small and Medium Enterprises (SMEs) at South Australia. The participants were recruited from SMEs who have various waste as their output, processing plants that use these wastes as inputs and end users of compost. Involvement of participants from these sources, processing plants and end-users ensures that data is collected along the organic compost supply chain. They provided information by means of semi-structured questionnaire. The questionnaire was initially introduced on the principle of the reverse supply chain within the circular economy that minimises waste by treating it as useful resources for value-added products for potential user groups. The questionnaire was self-developed based on literature knowledge of waste stream, logistics challenges in balancing supply and demand, contractual agreement among stakeholders, transaction cost economics and switching cost of doing business in an organic compost supply chain-Refer to appendix A .

Interview participants were sourced through Legatus Group contacts, and their recommended contacts were scheduled for interviews using a snowball sampling technique. Five interviews were conducted in regional South Australia, although a minimum of ten was intended for validity and generalisation of findings. However, due to resource constraints that resulted in a lower number of interviews. Further, COVID-19 restrained the people to participate as businesses were operating under multiple restrictions. The transcribed interviews were manually analysed into themes that are discussed in Section 4.

1.4 Report outline

The report is organised with the following sections. Section 1 provides the project background, the objectives and the study methodology. Section 2 discusses the composting process and statistics on organic volumes in the Legatus group regions. Section 3 employs a literature review to define Supply Chain Management (SCM) concepts, the Transaction Cost Economics (TCE) and Supply Chain Analysis (SCA) and how they relate to the circular economy. Section 4 includes an analysis of outcomes and the findings, focusing on the supply chain. Section 5 provides conclusions, recommendations and indicates future research opportunities.

SECTION 2

2 Composting Process

2.1 Defining composting

Composting is the biological decomposition of organic waste under controlled conditions to a state where storage, handling and land application can be achieved without adversely affecting the environment (Chen et al., 2011; Hansen et al., 1995). It is frequently referred to as nature's recycling method (Sweeten, 2008). According to Smith and Collins (2007),closely supported by Epstein (2017), composting is the biological decomposition and stabilization of organic matter derived from plants, animals or humans through the action of diverse microorganisms under controlled aerobic conditions.

It is a microbial-driven process. The term controlled in this definition implies that the process is managed or optimised to achieve desired results or objectives. Human control of the biological decomposition process is what differentiates composting from the natural decomposition of organic matter. Organic materials are recycled regardless of whether or not we compost them, but regulating and optimizing conditions ensures a faster process and the generation of a quality end product (Chen et al., 2011).

The final product of this biological process is a humus-like stable substrate, free of pathogens and plant seeds. When treated appropriately composted organics can be beneficially applied to land as an agent for soil amelioration or as an organic fertilizer. When the composting process is finished, a mature compost should have Carbohydrates(C) to Nitrogen(N) ratio i.e. C: N of 10-15:1, similar to that found in soil organic matter (Epstein, 2017). Compost with C: N higher than 10-15 can indicate that microbes are still active. If this compost is then applied to soil, the microbes will compete with plant roots for available nitrogen nutrients, resulting in poor plant performance. Compost is relatively low in plant nutrients compared to fertiliser, depending on the feedstock used.

Composting is linked to the ideas of reclamation, recycling, treatment, and disposal (Hansen et al., 1995). Reclamation and recycling are both aspects of resource stewardship that involve saving and reusing natural resources. In Australia, according to audits conducted by EC Sustainable (2011), approximately 33% of the waste material collected by Councils is food organics (including peelings) and 10% is garden vegetation. Surprisingly, such a large amount of organically active material is currently buried anaerobically (without air) in landfills, contributing more than 3% of Australia's total glasshouse gas emissions each year through methane gas production (which has 25 times the global warming potential of carbon dioxide) (ICAW Report 2021).

Compost quality is determined by several variables, including raw material particle size, aeration, moisture, temperature, pH, carbon to nitrogen ratio (C: N), and pathogen elimination. Most industrial composting facilities in Australia use open-air windrows to process recycled organics(Australian Organics Recycling Association, 2021). Figure 2 below shows the process of composting.

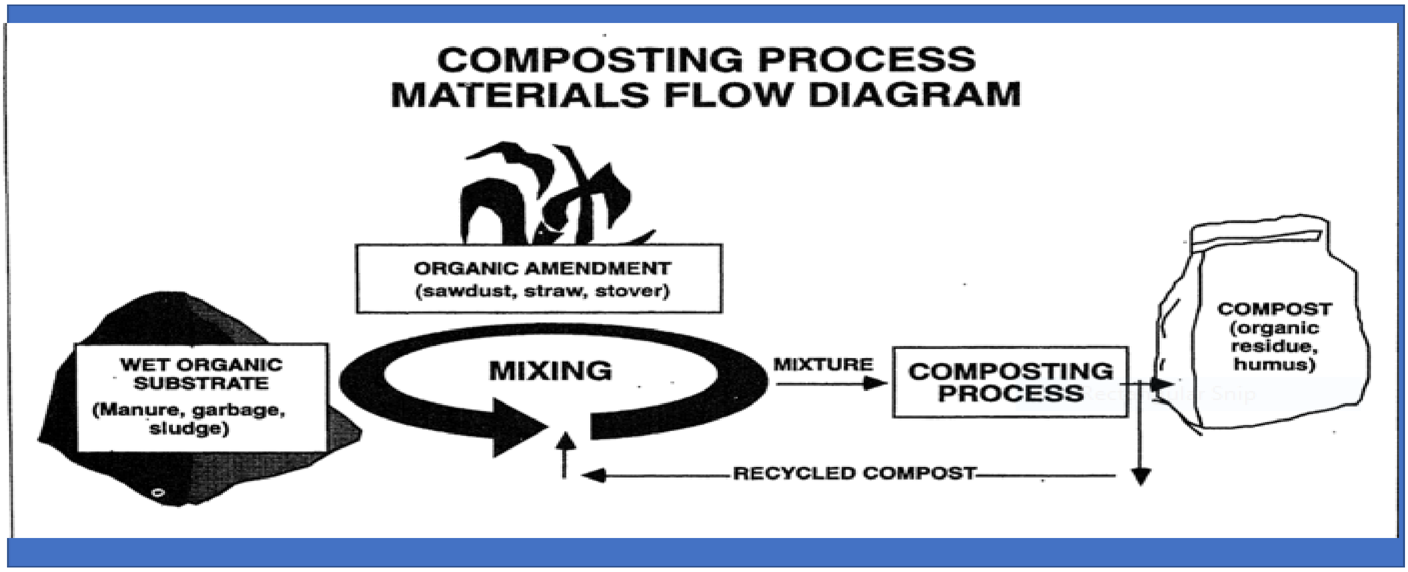

Figure 2 shows the composting process [Source Hansen et al. (1995)]

The composting process is depicted in the diagram above. The composting process begins when the inputs or materials for composting, such as manure, sawdust, sludge, and so on, are gathered. Composting operators break down large waste particles under controlled conditions by mixing, grinding, or chopping. The degradation of organic waste is a natural process that begins soon after the waste mixture is generated. Organic materials continue to decompose and are eventually converted to biologically stable humic substances—the mature or finished compost—once optimal physical conditions are established (such as microbes that require "food," suitable moisture, pH, temperature, and oxygen).

Compost as a soil amendment can be evaluated based on the following characteristics: Firstly**,** as soil conditioner value: Compost's superior value is its ability to act as a soil conditioner. Compost eventually turns into humus, which improves soil tilth. Compost promotes soil aggregation or "crumbing," which improves the soil's air-water relationships. Soil water holding capacity and water infiltration improve, erosion and soluble nitrogen leaching are reduced, and cation exchange capacity improves. Most composts produced today are used in the landscaping and nursery industries. Secondly, as nursery container media value: Compost has also been used effectively as an amendment in nursery and floristry container media. Incorporating disease suppressive composts in media with sufficient chemical and physical properties has successfully solved soilborne disease problems in nursery and glasshouse crops.

Composting provides several advantages. According to Chen et al. (2011), Composting typically reduces manure volume by 30 to 50%, which makes the material significantly more affordable to transport and provides many other benefits. Diverting urban solid waste organic material from landfills to composting has environmental benefits, such as lowering greenhouse gas emissions from landfills (GHGs) (Schott et al., 2016). It also encourages and sustains beneficial soil microbes and lost organisms due to crop production, drought, erosion, and other factors. Furthermore, using compost on land reduces the need for water by an average of 30% and dramatically improves soil quality that helps grow vegetables and fruit.

While composting present several advantages, it has its disadvantages. One of the significant downside of using compost is that there are risks with the composting processes, such as physical, chemical, and biological contaminants and negative direct/indirect environmental impacts (Pergola et al., 2020). When using food-driven compost, the main concern is loading the soil with metals, resulting in increased metal content in the crops (Hargreaves et al., 2008). Food compost has been reported to have high salt concentration, inhibiting plant growth, and negatively affecting soil structure. Against this background, contamination (which comes with costs) and other risks associated with composting are essential aspects of this study to examine in detail how best the current situation can be improved and suggest possible solutions to the risks.

When establishing a new composting plant to process biosolids and septage waste, several guidelines must be followed. The following are the primary documents to be aware of for this research:

- EPA Requirement for Waste-Derived Soil Enhancer (2010).
- EPA Guidelines for the Safe Handling and Reuse of Biosolids in South Australia (2020).
- EPA SA Compost Guideline (2019).
- Australian Standard for Compost, Soils and Mulches (AS 4454:2012).

There are also some limitations on the end-use of composts containing biosolids, as well as additional testing that may be required. A few standards are in place regarding contamination and other risks . The EPA recommends that the following Australian Standards be adopted in setting both environmental goals and quality parameters for compost products (Environment Protection Authority(EPA), 2019).

1. AS 4454–2012 Compost, soil conditioners and mulches.
2. AS4419–2003 Soils for landscaping and garden use.
3. AS 3743–2003 Potting mixes.
4. AS/NZS 5024 (INT)–2005 Potting mixes, composts, and other matrices: examination for legionellae.

These are voluntary standards for backyard gardeners and nurseries. It is recommended that large scale farm users, who are the subject of the study, be allowed to set their own standards and thus the cost of the compost. These standards should then be enforced by incorporating them into contract clauses.

2.2 Sources of regional organics

Several commercial compost producers are currently operating in South Australia, with most of them based in peri-urban areas and using waste collected by Councils and materials dropped off at municipal Waste Transfer Stations. These facilities do not process other materials, such as agricultural waste. Additional processing facilities, therefore, would be required to handle agricultural waste, particularly from rural communities located far from the peri-urban regions. Organic feedstocks appropriate for composting include a variety of materials from metropolitan and agricultural waste streams. These include the following:

- Untreated timber, sawdust, pallets, branches, straw, paper, cardboard.
- Food waste, crop residues, grape marc, olive pomace, brewery waste.
- Animal faeces, farmyard bedding and manure.
- Sludge from food and agricultural and meat production and processing.
- Biosolids and sludge from sewage treatment work.

2.3 Conclusion

This section has covered the fundamentals of organic composting. The information is essential in understanding the potential for regional supply chains. Before returning to the topic, the following section outlines the analytical concepts used in supply chain analysis as found in academic literature.

SECTION 3

3 Supply Chain Analysis (SCA)

3.1 Introduction

This section has described an over-arching concepts of SCA. Its relevance is obvious, given the title to this report. However, to operationalise the concept of SCA, a more applied focus is required. In the context of this research, so-called Transaction Cost Economics (TCE) will also be used. That will lead to its application to circular economy supply chain for organics in the following Sections.

3.2 Concepts of SCM &SCA

Christopher (1998) defines Supply Chain Management (SCM) as "the management of upstream and downstream relationships with suppliers and customers to deliver superior customer value at less cost to the supply chain as a whole". The SCM, according to Wang and Sedera (2011), provides numerous benefits via a framework that includes strategic, managerial, and operational dimensions. Furthermore, SCM can provide notable benefits such as improved collaboration, quality control, higher efficiency, lower overhead costs, risk mitigation, and shipping optimisation. These advantages are relevant in a sense that lack of effective SCM can result in inefficiency in supply chain, which may impede the development of its activities.

SCA consists of a quantitative analysis of inputs and outputs between firms, value-added activities and cost economy transaction of goods moving along a supply chain. Each participant is thought of as an independent agent along the chain where the transactions costs are minimised. The SCA process involves evaluating each stage of a supply chain, beginning with the acquisition of raw materials or supplies from suppliers and ending with delivering final products to customers. According to Simchi-Levi et al. (2004), an accurate SCA is more of a continuous task than a one-time effort which serves several purposes including: mapping the chain (using a flowchart) to get an overview of product flows, actors' positions and the interactions between each pair of transactors (known as dyads). Opportunities for innovation can be identified and investors' investment decisions can be improved through a better understanding of an existing supply chain.

For the purposes of this project, it is important also to link the concept of the Circular Economy (CE) to SCA. The CE refers to “a regenerative system in which resource input and waste, emission, and energy leakage are minimised by slowing, closing, and narrowing material and energy loops” (Geissdoerfer et al., 2017). Although not new, CE has recently emerged on the global stage as a potential organising principle around which multiple economic, political and social stakeholders can rally in their effort to pull the Earth back from the brink of environmental catastrophe (Andersen, 2007; Ghisellini et al., 2016; Hazen et al., 2018; Pearce & Turner, 1990). Despite its expanding popularity, CE has received little attention in the SCM literature (Tjahjono & Ripanti, 2019). There also remains a lack of detailed understanding in the literature regarding how SCM processes can be leveraged to achieve CE goals.

3.3 The Concept of Transaction Cost Economics (TCE)

Coase (1937) was the first to identify the Transaction Cost Economics (TCE) method to understand economic organisation, and, latter, a number of other scholars have examined it both theoretically and practically, for example, Coase (1991); Marsh (1998); Shelanski and Klein (1995); Williamson (1985); Williamson (2007). According to (Marsh, 1998), the TCE approach differs from more traditional economic approaches that emphasise market benefits and it appears to provide a foundation for a critique of the belief that market-based delivery systems are inherently superior.

The importance of opportunistic behaviour in TCE paradigm is central to this literature. The issue of trust is also important, as it is the opposite of the presumption of opportunistic behaviour. According to Milgrom and Roberts (1992), the following are the important dimensions that influence the nature of any transaction in the TCE, including in organic processing transactions:

- The uniqueness of the assets required to complete the transaction.
- The frequency with which similar transactions occur and the length of time during which they are repeated.
- The transaction's complexity and the uncertainty regarding what level of performance will be required.
- The complexity of evaluating transaction performance.
- The transaction's interconnectedness with other transactions involving other individuals.

The logical sequence of the TCE approach begins with the notion that efficiency along the supply chain is guaranteed if competition is effective: if sellers or buyers can switch among their trading partners, they will always exclude any party that is inefficient. However, competition is limited if it is expensive to switch. Switching costs means competition will not effectively constrain behaviour. Inefficiencies are now possible. The source of switching costs are the investments that must be dedicated to each relationship. These are called idiosyncratic investments or the degree of “asset specificity” (Williamson, 1980). Other researchers identify this element as the uniqueness of the assets required to complete the transaction (Milgrom & Roberts, 1992).

In effect, the parties to a transaction become locked together by the dedicated investments and they will tolerate inefficiencies in the relationship, up to the cost of switching to another partner. The situation is one in which one party can impose costs on or extract benefits from the other without payment. By way of example, the customer might desire credit from the supplier and the supplier will provide that credit, despite the costs, if it is cheaper than switching to another partner. Of course, there are many ways in which costs can be imposed or benefits extracted when parties become locked together by high switching costs e.g. reducing quality, increasing settlement times, altering delivery times etc.

Behaviour which imposes costs once the parties become committed or extracts benefits is opportunism. Williamson (1985) adds that opportunism is a key behavioural attribute of at least some economic agents. He describes it as “self-interest seeking with guile” (Williamson, 1980) which means that parties to a transaction are not just self-interested but will also act deviously and cheat if it serves their interests.

The costs of opportunism can be high and so parties that are locked together by switching costs will try to constrain opportunism by entering into agreements with the other party to limit that potential. These agreements attempt to specify, monitor, and enforce rules which limit opportunism. Of course, it is costly to do those things, but they will reduce (but not eliminate) the risk of failure in the relationship. All these lead to the definition of Transaction Costs (TC): They are costs incurred in governing (i.e. limiting) the potential for opportunism by specifying, monitoring, and enforcing contractual arrangements, and they also include the expected cost of failure.

All these points are relevant to our examination of organics processing. We need to understand the idiosyncratic investments incurred by parties along the supply chain. We also need to assess the difficulties in the transactions that make it likely to be costly to specify, monitor and enforce arrangements and we need to assess the likelihood and the consequences of failure. The interviews with potential participants along the regional organics supply chain, found in Section 4, follow that progression. In short, the analysis will follow these research questions:

1. Are there idiosyncratic investments required along the supply chain for organics that will limit the ability of parties to switch?
2. If so, what contractual arrangements can be entered into to limit the potential for opportunism? In other words what must be specified, how will that be monitored and enforced and how likely is it to fail, with what consequences? This amounts to an assessment of how costly it will be to conduct the relevant transactions i.e. what are the likely transaction costs?
3. Is it likely that the transaction costs are so high that they are a significant impediment to the emergence of these organics supply chains?
4. If transaction costs are a likely impediment, what can be done to reduce them?

The concepts of Total Cost (TC) (Cavinato, 1991), lifecycle costing (Jackson Jr & Ostrom, 1980), product life cycle costs (Shields & Young, 1992) and total cost of ownership (Ellram, 1994; Ellram, 1993) are all similar ideas. For the appropriate valuation of buying situations, these principles propose that supply managers take a long-term approach rather than a short-term initial-price approach (Ferrin & Plank, 2002). All three concepts underpin the procurement valuation construct. To begin, cost must be considered from a long-term perspective, considering factors other than the initial purchase price. Secondly, supply managers must assess the impact of other business functions or other company operations on a purchase's valuation. Finally, to appropriately evaluate a buying situation, supply chain management must comprehend and quantify the cost impact of all linked actions. All these are essential elements of future business decisions concerning organic processing. This study focuses on understanding the challenges to processing organic compost.

It is critical to include the idea of Total Costs of Ownership (TCO), related to transaction costs, in the analysis of the organic compost supply chain and its cost implications. TCO can be defined as “an innovative philosophy aimed at developing an understanding of the ‘true’ cost of doing business with a particular supplier for a particular good or service” (Ellram, 1994, p. 171). Similarly, Degraeve and Roodhooft (1999), suggest TCO as attempting “to quantify all of the costs related to the purchase of a given quantity of products or services from a given supplier. TCO is some amalgamation of the price associated with the transaction and the cost of participating in that transaction, i.e. the TC. Understanding TCO is beneficial as it not only improves internal and external communication, but also offers improved insight into the firm’s resource allocation issues. In relation to this study, one advantage of implementing TCO in businesses is that it allows for a more effective clarification of supplier performance expectations for both the buying firm and the suppliers. Aside from this benefit, objective data for negotiations and a more focused long-term approach to supplier cooperation have been highlighted as advantages of using TCO.

3.4 Conclusion

This section has linked the project to the academic literature, using the concepts of supply Chain Analysis, Transaction Costs Economics and Total Costs of Ownership. The following section applies the concepts to the subject at hand by following each pairing of parties along the supply chain.

SECTION 4

4 The supply chain analysis for regional organics

4.1 Introduction

This section is based on interviews with recruited participants along the supply chain for organics in regional South Australia. It comprises three major parties and their primary transactional partners: suppliers, processors, and users. The section uses interviewees' insights to provide answers to the questions raised in section 3. The list of interviewees can be found in the Table 1 below.

Table 1 : Interviews Summary Report

No	Name of Company	Category	Description	Experience with Inorganic compost	Compost materials
1	Mr A J Hall l (Family business), **C1**	Source/User	Family farm located in the Clare and Gilbert Valley Council, approx. 20mins drive South East of Clare. Sheep and Grain Production. The soils within their region are usually within acidic PH levels.	5-8 years	Chicken manure, Chicken Manure and BioSolids
2	Princess Royal Station (cattle feedlot), **C2**	Source/User	Operations include high-quality grain and grass-finished beef, large-scale cereal grain production, livestock trading, Angus breeding, lamb production, an expanding internal freight division and live export quarantine.	6 years	Generate a wide variety of produce including breeding of cattle, feeding of cattle and sheep, agricultural cropping, cattle commission services, large truck freight operations, also dabbling wine production. The lagoons give us the ability to use the liquid waste for irrigation and as a natural fertilizer purposes for nearby farming. The solid waste removed from the pens is composted, heated and all bugs are removed.
3	Morgan Sawmill Jamestown, **C3**	Source/ User	Morgan Sawmill is a family business, the products range is extensive and includes posts, structural timber, pallets, bins/boxes, woodchips, forestry plantation sawdust and decking to name a few.	12 years	They are producing ~ 25 cubic meters of mill waste per week All of this is currently being sold; local customers are prioritized first

4	Clare Valley Wine & Grape Association, **C4**	Source/User	It is a group of Valley grape growers and winemakers who brought their talents together in a single association.	5 years	Dominated by small growers and winemakers (viticulture).
5	Peats Soil Processor, **C5**	Processors	One of the interviewed processor Peats Soil operates across 4 sites, receiving and processing food waste, green organics, manure, and sewage sludge. Peats Soil have a wide range of products available in bags and bulk, including seed raising mixes, soil conditioners, potting mixes, organic blends, loams, mulches etc.	1 year	They receive and process much of metropolitan Adelaide's green organics through council kerbside and business collections, as well as food organics from hotels, supermarkets, schools, office buildings, food processors and manufacturers utilizing their globally famous BiobiN organic waste collection and on-site processing facilities amongst many other collection method

4.2 Sources of organic Waste

The sources of organic materials include green waste, kerbside collected green waste (which may include food waste), untreated timber, sawdust, pallet straw, paper, cardboard, manure and sludge, waste from meat and fish preparation, and so on. From this list, a small number of sources indicative of regional South Australia have been chosen, from broadacre farming, timber processing and animal production.

Primary producers within the Legatus region are a large and diverse source of organics. Three volunteers were chosen and asked semi-structured questions about their company's organic waste management practices. Recognising this as a small sample, interviewees were invited to comment on trends and practices within the Mid North's broader agricultural industry. Each participant is employed within a target industry for locally produced compost.

The interviews **(C1,C2)** indicated that raw materials are currently being repurposed rather than discarded. As a result, organic waste is not waste in and of itself but rather a resource that is already in use. The current uses are low-cost and low-value options that require almost no specialised, idiosyncratic, or peculiar investment. Furthermore, the sources are complex and diverse and are unorganised in business associations, so there is no additional framework of organisation to help deal with the logistical problems that might exist. Current uses are simple and often informal, and processors will need to attract these materials to the higher value option of composting by offering attractive TCO.

With regards to participating in a future organic processing supply chain, the interviews **(C5)** indicated that suppliers do not need to make significant, dedicated investments. Their role is to deliver material meeting specifications to the processor, who will then prepare them for processing and charge a fee for doing so. Other arrangements are possible, but that is the common practice anticipated by potential suppliers. This means that sources of organics are largely insulated from the potential for opportunism: if processors were to impose significant costs on the suppliers they could return to current arrangements at little or no costs.

The supplier will need to monitor performance against the supply specification and will incur TC in doing so. It will require constant control of the organic material, which adds complexity and some uncertainty, hence increasing TC. However, that control is unlikely to be expensive as it concerns the core business of the supplier. For example, a wheat grower must, in any case, monitor their crop (for chemical residues, contamination, etc.) and that monitoring will extend to any residue sent for composting. In terms of failure costs (the other element in TC), the research found that by incurring the costs to specify and monitor arrangements, its likelihood can be effectively constrained for sources. The expected cost of failure is the product of the likelihood and the consequences but, in this case, the consequences are primarily having the material returned and having to revert to the original low-cost use. So, they are not thought to be prohibitive.

The implication for this study is that, while by no means a simple matter, the logistical challenges confronting potential suppliers appear to be minor. Thus, transaction costs are unlikely to be a significant impediment to suppliers' involvement. As a result, the barriers to participation in the proposal for more processing plants are relatively low for sources. We now turn to processors with the same analysis.

4.3 Processors of organics

The view has emerged that the logistics of the supply chain are expensive to manage for processors. One participant from Peats Soil **(C5)** was recruited and asked about their business’s organic waste management processing practices. Peat Soil operates across four sites in South Australia, receiving and processing food waste, green organics, manure, and sewage sludge. Through the council's kerbside collection, they receive and process a large portion of metropolitan Adelaide's green organics. Peats Soil offers a wide variety of products available in bags and bulk, including seed raising mixes, soil conditioners, potting mixes, organic blends, loams, mulches, and more.

The interview questions were designed to test the researcher's understanding gleaned from previous interviews with sources and users. The interviewee indicated that the processor created a wide range of products (about 300 potential products in the range), with six to seven as primary products.

Regarding asset specificity, the small-scale composting relevant to regional processing is, in general, not capital intensive, which limits the dedicated investments required for processing. For example, trucks and front-end loaders are used, but they are generic machines that can easily be switched to other uses. This is unlike some very large processing facilities which use rotating equipment to aerate the materials. Processors do need to invest in shredders and aerating equipment, but it is possible to service small scale plant with mobile equipment. All of this reduces switching costs and limits the exposure of processors. To further limit capital investments, a small regional plant will likely produce a limited number of products.

The last point implies that the actual product specification will need to be agreed upon with the local users in advance or, in some cases, they will have to process the products on a Make to Order (MTO) basis. Either option will incur significant transaction cost (TC). There is a range of other issues which will need to be resolved, and TC will be incurred to do so. For example, users will need contracts that specify delivery times, payment arrangements, monitoring and enforcement procedures all of which must be decided upon by both parties.

Contamination of inputs has been identified as a critical issue by all supply chain stakeholders. This is particularly so where the user wants a clean and green environment. Contamination poses costs of rejection and claims for damages, as well as costs in terms of reputational risk, health, and safety risks. On occasions, processors have rejected some feedstock due to high levels of contaminants and manual and/or mechanical sorting is necessary for the removal of physical contaminants/inclusions such as litter, plastic, glass, and stones, including maintaining records of all incoming waste. All that adds to the TC. Furthermore, it has emerged that the agreements that processors reach with users will have ramifications for the arrangements that processors make with suppliers. For example, the type of compost that will be sold in part determines what inputs are required. This implies that users will want to specify the product and processors will need to balance that specification with those agreed to by the sources.

The problem of contamination and users' specifications obviously complicates the situation. Given the difficulties and frequency of the transactions, specification and monitoring costs are likely to be significant. Enforcement of specifications is also a component of TC. Processors will need to write contracts that can be enforced through the legal system. However, experience from the interviews suggests that informal agreements enforce specifications which is expected. Small and regional transactions are often supported by community-based, informal practices, making enforcement relatively inexpensive, albeit somewhat uncertain. That reduces TC in some respects, although it can also increase the expected cost of failure.

Asked about whether they use standards as a compliance requirement (AS 4454:2012) for their products, the interviewee's (**C5**) response was that while they are used, they are both optional and vague *"and therefore need to be improved"*.

In terms of the expected cost of failure, while the contractual arrangements will reduce its likelihood, they will be imperfect, so some failure is possible. Even if the likelihood is low, the consequences of failure are severe and so this component of transaction costs is likely to be significant. The point is that contaminated soil additives can destroy crops, which are expensive for annual crops and even more so for perennial crops.

Overall, this supply chain analysis indicates that processors face high transaction costs, especially in monitoring and dealing with the consequences of contamination. These transaction costs are high and are likely to outweigh those faced by suppliers. Reducing transaction costs for processors is expected to boost the development of these organic compost supply chains significantly.

4.4 Users of organics

Turning now to regional users of organics (**C2,C3,C4**), they are most often farmers. Farmers are currently using a combination of synthetic fertilisers, biosolids and manure to improve soil productivity. Most farmers currently source synthetic, inorganic fertiliser through long and distant supply chains. Some have reported that they use chicken manure; both pure and a blend of manure with straw bedding, mostly collected from farms.

According to the analysis, current supply chain logistics are problematic because the entire season's fertiliser is ordered at once, posing cash flow and storage issues. This implies that switching to organics will be a major change for many broadacre farmers and major changes are subject to uncertainties and apprehension, adding to TC. Furthermore, when it comes to switching costs, interviews revealed that the current supply of synthetic fertiliser is in pellet form, but the organics might be incompatible with the spreader equipment currently used, requiring users to make financial commitments by purchasing new equipment, exposing them to the potential for opportunism on the part of the processors.

Asked whether they have used organic fertiliser: “The interviewee responded

“We prefer synthetic fertiliser because it gives more return on Investment”

Also, the fact that soil additives are applied in an integrated, seasonal process, means that a failure in some future local supply chain will result in additional TC because the right, complementary alternative must be sourced or, more likely, users will hold sufficient stockpiles to complete the season. Similarly, different crops will necessitate different composts, so users must specify the qualities required by the processor. This procedure will be time-consuming and costly, as it will include soil testing and other methods. Adding to the complications is that it seems likely that inorganic fertilizers will be used in conjunction with any organic compost, making specifications more difficult.

As to monitoring, users will be unlikely to monitor the compost per se but will instead monitor crop performance against expectations as a means of assessing the performance of the input. This will incur some additional cost. In short, monitoring procedures are expected to be straightforward for users because processors will simply monitor on their behalf and provide assurances; however, users will monitor crop performance against expectations, which will incur some additional cost. The point is that contaminated soil additives can destroy crops, that is expensive particularly perennial plants, for example, olive trees or grape vines.

In terms of resolving a dispute, the interviews showed that both supplier and users are likely to prefer to resolve their dispute through negotiations, although processors normally refer to the contractual penalty clauses in the contract. It is the best way of resolving a dispute without jeopardizing the business relationships.

Finally, the last element of TC, the expected costs of contractual arrangement failure, are expected to be high for users. As with processors, the likelihood of failure for users can be constrained by incurring TC in specification and monitoring but the consequences can be severe. The overall conclusion is that users face high transaction costs, particularly the expected costs of failure.

4.5 Conclusion

Following an examination of the TC along the potential supply chain, the overall conclusion is that they are significant, particularly for processors and users. As such, they are likely to constitute a significant impediment to the emergence of this activity. The final section suggests some possible remedies and offer final remarks.

SECTION 5

5 Summary

5.1 Some remedies

The analysis indicates some remedies for the high TC that have been identified. The first is to create more substantial, stronger organisations (aka, economic institutions) that provide a framework in which transactions might be more cheaply organised. TC are reduced by organisations with membership rules and procedures that address the logistical challenges by reducing the costs of specifying, monitoring, and enforcing contractual arrangements and the risk of those arrangements failing. The key is that these institutions do not currently exist and so must be purpose-built. The point is best illustrated with an example below:

Consider Regional Composting Cooperatives (RCC), formed by all participants along the supply chain. The RCC could establish membership rules that help reduce TC. For example, we have identified quality control as a key issue. The cooperative might have membership rules which require participants to use only accredited testing laboratories or to meet a checklist of criteria. Along the same lines, an alternative would be to establish a council-led institution such as the Organic Waste Management Authority (OWMA). The OWMA might operate the processing plant or write contracts for others to do so. It would be a trusted organisation which could act as a broker among participants and provide targeted assistance.

The second suggested remedy is to take specific action to address the anticipated problems identified in the interviews. This will necessitate the state government's involvement and may include, for example, providing a sampling and testing service to reduce monitoring costs or introducing a joint scheme to underwrite the costs of failure. Other suggested strategies or remedies include activities to increase trust in the composting industry by training and educating supply chain participants, particularly about contamination, via roadshows and other activities.

In terms of logistics needs, it is recommended that the number of Third-Party Logistics (3PL) providers be increased. A 3PL provider is a specialised company that provides customers with distribution, storage, transportation, and fulfilment services. They offer full-service management of specific services. In this study's supply chain, they either collect and deliver materials from sources to processors or those who collect and deliver organic compost products to end users. The practise of increasing the number of players in logistics services will increase competition among service providers. This will result in lower transportation costs because suppliers, processors, and users will be able to negotiate transportation costs and choose who will provide the best service, resulting in cost savings and increased efficiency.

In conclusion, many of these solutions will necessitate a stronger collective voice for the Legatus region's fifteen Councils. This will aid in the development of policies and acquisition of funding to address the issues. More relevant and coordinated research in feasibility studies, increased community participation and government interventions to improve composting processes, handling, and efficiency are required. These solutions can be implemented by enlisting the help of more supply chain professionals, consultants, and researchers.

5.2 Limitations of this study and the need for future research

This study focused solely on potential sources, processing and users, and applications in large-scale industrial applications. This hampered the inclusion of community-level sourcing and applications. Its impact on social well-being was beyond its purview. Furthermore, many industry members were largely unavailable at the time of the interview because it was the season of peak activity. COVID-19 lockdowns and restrictions meant that the target number of interviews could not be met, limiting the number of interviewees to get a clearer picture of the information we were gathering.

In terms of future research, operational composting conditions and raw material conditioning have also been extensively researched, as evidenced by the scientific literature. Given this context, a future project must include three pillars of sustainability. These three pillars are colloquially known as "People, Planet, and Profits (PPP)." Sustainability is the integration of environmental health, social equity, and economic viability to create thriving, healthy, diverse, and resilient communities for this generation and generations to come. The practice of sustainability recognizes how these issues are interconnected and requires a system approach and an acknowledgement of complexity. This kind of research could give different dimensions to organic compost supply chain design. Furthermore, other research efforts that address odour control, toxic contamination, materials handling, and other methods for demonstrating new compost handling methods could be explored.

5.3 Concluding remarks

The cost of composting is likely to be low enough so that, given the value of the output for this activity, it is likely to be of net benefit to the parties along the supply chain. However, the transaction costs associated with transactions along the supply chain are high for some participants and might be so high as to impede the activity. If that assessment is reached, it suggests that action is needed to reduce transaction costs. Without such action, it will be hard to take up the opportunity, at least not comprehensively.

Acknowledgements

I want to express my gratitude to everyone who helped me with my internship: David Beecham, Associate Professor Himanshu Shee, Dr Paul Chapman, Simon Millcock, and Alex Mullany. They all deserve special recognition for their unwavering support throughout the internship. It was an eye-opening experience, and we hope to get in touch again soon. It would have been a pleasure to meet you in person if COVID 19 restrictions and lockdown prohibitions were not there.

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