Towards monitoring and managing the production of cadastral information in land information infrastructures using supply chain mapping and the Supply Chain Operations Reference (SCOR) model

Edward Kurwakumire[1,2], Serena Coetzee[1], Peter Schmitz[1,3,4]

[1]Centre for Geoinformation Science, Department of Geography, Geoinformatics and Meteorology, University of Pretoria, Hatfield, Pretoria, South Africa
[2]Geomatics Department, Tshwane University of Technology, Pretoria, South Africa, KurwakumireE@tut.ac.za
[3]Department of Geography, UNISA, Christiaan de Wet Rd, Florida, South Africa
[4]Fakultät für Vermessung, Informatik und Mathematik, Hochschule für Technik, Stuttgart, Schellingstrasse 24, D-70174, Stuttgart, Germany

DOI: http://dx.doi.org/10.4314/sajg.v9i2.12

Abstract

Coping with rapid urbanisation and the impacts of climate change requires effective land management. Quality land information is essential for this. A land information infrastructure is a collaborative and coordinated initiative aimed at providing land information from different organisations, such as municipalities, government departments and private companies, to diverse user communities. A land information infrastructure is complex, spanning information streams through many organisations and technical systems, and presenting challenges for managing and monitoring the production of land information. In the manufacturing field, a supply chain refers to the stream of activities from the initial source to the delivery of end products to customers, and supply chain management is directed at optimising the creation of the products of such a chain. The Supply Chain Operations Reference (SCOR) model is widely used for analysing supply chain processes in order to quantify and improve product and service delivery, and it has also been applied to geographical information supply chains. In this study, the SCOR model is applied to the supply chain processes in a South African case study of a land information infrastructure focusing on the production of cadastral information products. The supply chain comprises a land developer, a land surveying firm, the Surveyor General's and Deeds Offices, a geospatial data vendor and the end customer. This supply chain is mapped and analysed using supply chain mapping and the SCOR model, and based on this, the complexity of the land information infrastructure is revealed. The study shows that supply chain management and the SCOR model can be used to analyse, monitor and manage the production processes of land information within a land information infrastructure.

1. Introduction

Land information is at the core of spatial planning and all space-related decision making (Indrajit et al., 2020) because all human activities occur on land, typically subdivided into land parcels. Spatial planning and land management are essential to ensure sustainable land and environmental management practices (Gorzym-Wilkowski, 2017). Consistent and up-to-date land information is a prerequisite for effective land administration and management (Dale and McLaren, 1999; Heiskanen et al., 2017; Indrajit et al., 2020), environmental management and land-use planning (Zeng and Cleon, 2018), and disaster management and resilience (Alamdar et al., 2016; Rajabifard et al., 2018).

A land information infrastructure makes land information available (Rajabifard et al., 2018; Huang et al., 2019) to a wide range of users for consumption or the development of further value-added land information-related products. Nations have thus been developing land information infrastructures to support the storage, management, access, use and reuse of land-related information. On account of the wide application of land information, there is a greater need to manage and monitor the processes resulting in the production, distribution and delivery of land information. This study analyses this coordinated flow of land information.

Land information infrastructures in today's complex and modern world face the challenge of the continuously changing product and service needs of customers (Zwirowicz-Rutkowska, 2017). This requires land-information infrastructures to be agile and to evolve (Coetzee, 2018) in order to address the dynamic needs of customers. To ensure that a land information infrastructure is effective, the constituent components and the flow of information through it need to be understood. This understanding involves taking cognisance of problems that could occur in the land information stream, such as possibilities for the late delivery of input data, the delivery of wrong data from suppliers or the use of a time-consuming and labour-intensive land information production workflow. These problems can be resolved by monitoring and managing the processes involved in the generation and distribution of land information. Monitoring and managing the flow results in improved turnaround times from the sourcing of raw land-related data to the delivery of final land information products to end users. Because a land information infrastructure is complex (Steudler, 2004) and comprises a system of systems that spans different organisations (Cooper et al., 2019; Ronzhin et al., 2019) from different sectors and with varying organisational mandates, to fully comprehend the infrastructure and how its constituent parts operate is challenging.

To achieve this, the supply chain mapping concept was borrowed from manufacturing and applied to land information. In this study, the Supply Chain Operations Reference (SCOR) model is used to model a land information infrastructure supply chain in South Africa where the focus is on the production of land information products through supply chains, in which several organisations are involved. SCOR can map simple and complex processes, hence its usefulness for application in this study (Supply Chain Council, 2012). Land information is important because it is considered to be a base or fundamental data theme in many spatial data infrastructures (ANZLIC, 2010).

The purpose of this paper is to visualise the land information infrastructure through mapping the flow of land information using supply chain mapping and the SCOR model to show the complex nature of the infrastructure and the process of generating information. Furthermore, the complex processes depicted are analysed to understand and explain the operation of the infrastructure in creating land information. This paper focuses on the production of cadastral information, the backbone of any land information infrastructure, as it supports all aspects of land management and sustainable development (Williamson et al., 2008). This paper builds on work presented by Kurwakumire et al. (2013) and Kurwakumire et al. (2014).

This paper is organised as follows: Section 2 discusses prior literature on the assessment and complexity of land information infrastructures. Section 3 introduces the concept of supply chains, supply chain management and the SCOR model. Section 4 presents the results of supply chain and SCOR mapping of the production process of land information. Section 5 presents a discussion in which the benefits of visualising the operation of the land information infrastructure are detailed, and Section 6, the conclusions of this study.

2. Related work

The complexity of land information infrastructures was already envisioned many years ago (Kaufmann and Steudler, 1998). This complexity is due to the evolving nature of land rights (Williamson, 2000) and the manner in which cadastral systems could be modelled and presented as information systems. Nowadays, they have become even more complex because they need to accommodate and manage dynamic sets of complicated relationships between humans and land on account of the increasing diversity of rights, restrictions and responsibilities over land, sometimes depicted as three-dimensional land uses (van Oosterom et al., 2020). Apart from this diversity, and owing to continuous developments in information and communications technologies, land information infrastructures are dynamic and are in a state of constant evolution.

The land administration domain model (LADM) was developed to capture the complex relationships inherent in land information (ISO 19152:2012). The LADM is a conceptual model that reveals the complexity of land-holding concepts and the relationships between them. It does not reveal the complexity of processes involved in land information production. The latter is an objective of the study reported in this paper.

This complexity and the dynamic nature of land information infrastructures (Steudler, 2004) calls for management approaches that can deal with complex processes that change over time, and it justifies the application of SCOR and supply chain mapping in modelling land information processes. Since land information infrastructures are in constant evolution, supply chain design and the mapping of the land information infrastructure have to evolve in order to adapt to new technologies and user demands. Supply chain design should constantly evolve (Badenhorst-Weiss and Nel, 2011) to achieve supply chain effectiveness. This is important because markets and user needs are dynamic (Celikbilek and Süer, 2020). Supply chain mapping and the SCOR model are tools that can map complex processes and manage their operation (Supply Chain Council, 2012), hence their use in this study to model and analyse the complex nature of land information infrastructures. This complex nature results in complex processes for creating land information products and services.

As seen in Figure 1, the production of geographical information can be represented as a value chain. It is a collaborative effort in which a number of organisations participate (Chimhamhiwa et al., 2009; Chimhamhiwa, 2010; Cooper et al., 2019) in some form of conveyor belt from raw materials to final products (Krek and Frank, 2000). This conveyor belt resembles a supply chain. Crompvoets et al. (2010) argue that the value-addition processes of spatial data are complex as opposed to the simple value chain presented in Krek and Frank (2000). According to Christopher (2011), the supply chain and value chain are similar concepts in the information age. In this paper, the terms, supply chain and value chain, are used interchangeably. Owing to the view that land information is produced through a supply chain, supply chain management and SCOR are therefore well suited to mapping and the analysis of production processes in a land information infrastructure.

Figure 1. Geographical information value chain (Krek and Frank, 2000: figure 2, page 4)

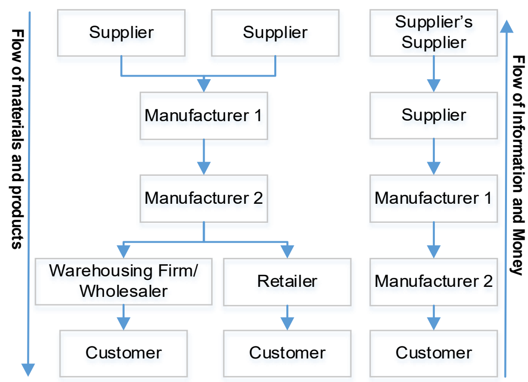

Figure 2: Examples of supply chains

In the studies of geographical information value chains by Krek and Frank (2000) and Van Loenen and Zevenbergen (2010), there is consensus that a value stream of processes transforms input data to value-added products. Various studies have been conducted on the assessment of spatial information infrastructures. For example, Tulloch and Epstein (2002) assessed the effectiveness of land information infrastructures based on an ultimate efficiency indicator for achieving democratisation of information, and Chimhamwiwa et al. (2009), on service delivery performance. An example of benefit assessment can be found in Crompvoets et al. (2010), which is based on an actor-network focus. Similarly, spatial data infrastructures were assessed by Giff et al. (2008) and Zwirowicz-Rutkowska (2014) using a multi-view framework; by De Vries et al. (2011) through cultivation and design approaches, and a range of other techniques which were used in Grus et al. (2007), Kok and Van Loenen (2005), Vancauwenberghe et al. (2018) and Kalantari-Oskouei et al. (2019). This paper presents a novel viewpoint on an assessment of land information infrastructures through the use of supply chain management and the SCOR model.

3. Supply chains and Supply Chain Operations Reference Model (SCOR)

3.1. Supply chains

A supply chain comprises a group of interdependent organisations that collectively manage the stream of operations that transform raw materials into value-added products or services and deliver them to customers (Christopher, 2011; Daneshjo, 2016). Organisations are involved as manufacturers, suppliers, transporters, warehousing firms, retailers and customers (Chopra and

Meindl, 2013). A supply chain can be represented by a graph of nodes (organisations) (Figure 2). Each node performs transformation operations that contribute to the value of the goods being transported through the chain to fulfil a customer request (Janvier-James, 2012).

3.2. Supply chain management

Organisations are continuously seeking methods to more effectively coordinate flows of materials in and out of them. Supply chain management refers to the measures that integrate supply chain organisations and markets to deliver value-added products and services to customers at the best possible cost (Gunasekaran and Ngai, 2004; Razavi et al., 2016). It involves managing upstream and downstream relationships between suppliers and customers (Christopher, 2011; Sukati et al., 2011). Supply chain management has been adopted in the manufacturing domain to improve logistics execution, which has led to reduced production costs (Akkermans et al., 2003). Gunasekaran and Ngai (2004) emphasises the flexibility and responsiveness of the supply chain for achieving superior customer value.

The total supply chain network rather than individual components, organisations or processes, should be managed, since any supply chain is as strong as its weakest link (Min and Zhou, 2002). Chimhamhiwa et al. (2009) emphasises the need for independent organisations in a value network to effectively collaborate. This is because the success of each organisation involved in the chain depends on the overall success and operational effectiveness of the total supply chain (Ibrahim and Hamid, 2014). Improving the effectiveness of the total supply chain is required for achieving customer value at reduced supply chain costs. Chimhamhiwa et al. (2009) concurs in a study of producing and delivering deeds that the business processes in a value stream need to be analysed as one integrated chain. This would allow for improvements to the supply chain as a whole.

3.3. Supply chain operations reference (SCOR) model

The supply chain operations reference model (SCOR) was initially developed by the Supply Chain Council as a platform to visualise supply chain management processes. The Supply Chain Council is a non-profit global consortium developed in 1996 with the aim of assisting organisations to improve supply chain processes. SCOR describes all business activities that need to be carried out in order to fulfil a customer's request (Supply Chain Council, 2012). SCOR is now owned by the American Production and Inventory Control Society (APICS) after the incorporation of the Supply Chain Council into APICS, which is available online at https://www.apics.org/apics-for-business. SCOR integrates business processes, performance metrics, best practices and technology to improve the effectiveness of supply chain management and to determine supply chain management improvement activities (Supply Chain Council, 2012).

As depicted in Figure 3, SCOR is based on five distinct processes namely: (1) Plan, (2) Source, (3) Make, (4) Deliver and (5) Return (Schmitz, 2016). These are used to map simple and complex supply chains. SCOR provides a framework for describing all activities and business processes that would have to take place in order to satisfy a customer's request (Supply Chain Council, 2012). It includes a mechanism for identifying and organising the performance metrics of supply chains and relating them to their respective strategic goals and business processes (Jung et al., 2015).

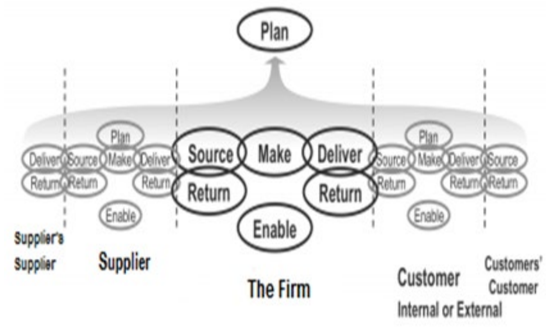

Figure 3: SCOR adapted from Supply Chain Council (2012)

Element	Description
sS1	Source: Stocked Product
sS2	Source: Make-to-Order Product
sS3	Source: Engineer-to-Order Product
sM1	Make: Stocked Product
sM2	Make: Make-to-Order Product
sM3	Make: Engineer-to-Order Product
sD1	Deliver: Stocked Product
sD2	Deliver: Make-to-Order Product
sD3	Deliver: Engineer-to-Order Product
sDR1	Deliver Return: Defective Product
sSR1	Source Return: Defective Product

Table 1: Level 2 SCOR Version 12.0 Elements

Level 1 mapping using SCOR depicts the process types at a high level using Plan (sP), Source (sS), Make (sM), Deliver (sD) and Return (sR). Level 1 mapping defines the scope of the supply chain. Level 2 mapping breaks down the level 1 process types into process categories such as make-to-stock, make-to-order and engineer-to-order for a make-process type. In level 2, the operational strategies for achieving the supply chain performance targets laid out in level 1 are defined. Level 3 further breaks down level 2 process categories into process elements, such as for Source (Level 1), sS1 (Level 2 – Source: Stocked product), the level 3 elements are sS1.1-Schedule Deliveries, sS1.2 – Receive Product, sS1.3 – Verify Product, sS1.4 – Transfer Product and sS1.5 – Authorise Payment (Supply Chain Council, 2012).

Thus with each level, the detail of mapping is increased and so is the ability to analyse the supply chain. This study uses level 2 mapping, as opposed to level 1, to demonstrate the interaction of process categories at an intermediate level of complexity to clarify the understanding of the production processes of land information at a high but more informative level. Table 1 summarises the SCOR model elements and their descriptions for level 2 mapping.

4. Results of the South African Case Study

The SCOR mapping adopted in this study presents the scope of the land information infrastructure as comprising seven entities, namely the upstream customer (land developer), the land surveying firm (supplier's supplier), the Surveyor General's Office (supplier), the Deeds Office (supplier), a geospatial data vendor (manufacturer) and the downstream customer. The concept of upstream and downstream works in the context that a river flows from upstream to downstream; thus upstream refers to suppliers and downstream to customers. The first subsection presents generic supply chain mapping, which provides a workflow showing all activities and inter-linkages between organisations and processes in the land information production process without necessarily adopting a universal approach, notation or language for the mapping. In the second subsection, a SCOR-based approach for mapping the land information infrastructure is presented. The SCOR presentation of the land information supply chain is more detailed and specific regarding the activities occurring at each stage of the supply chain.

Owing to the broadness of scope in terms of land information, this study focuses on the supply chain for producing cadastral information products. Cadastral products fundamentally contain information about boundaries, ownership, land use and the value of land parcels. The importance of cadastral information is that it provides the spatial integrity and unique identification of properties or land parcels in the land information infrastructure (Williamson et al., 2008).

4.1. Supply chain mapping of the land information infrastructure

In Figure 4, the land developer, who is the initial upstream customer, enables the land information infrastructure supply chain through a request for a survey of land. A subdivision survey is considered in this study. This customer is interested in an upstream finished land information product, referred to as a general plan, which is generated by a professional land surveyor (PLS) operating a land surveying firm.

The professional land surveyor performs data searches and a field survey and uses software to perform computations and to design the general plan. These are specific manufacturing processes.

After creating this general or cadastral plan (land information product), this product is sent to or lodged at (supplied) the Surveyor General's (SG) Office for examination (quality control/verification) of conformance to surveying and mapping standards in accordance with specifications outlined in the Land Survey Act of 1997.

If the general plan and survey records submitted meet the required quality standards in terms of accuracy, coordinate consistency and completeness of diagrams and survey records, then the survey is approved. A copy of the diagram is then sent to the professional land surveyor who sends it to the original customer. The Surveyor General's Office then adds the new diagram to the cadastral layer, which is part of the fundamental data in the land information infrastructure, through coordinate geometry, format changes and exporting this data to a data warehouse.

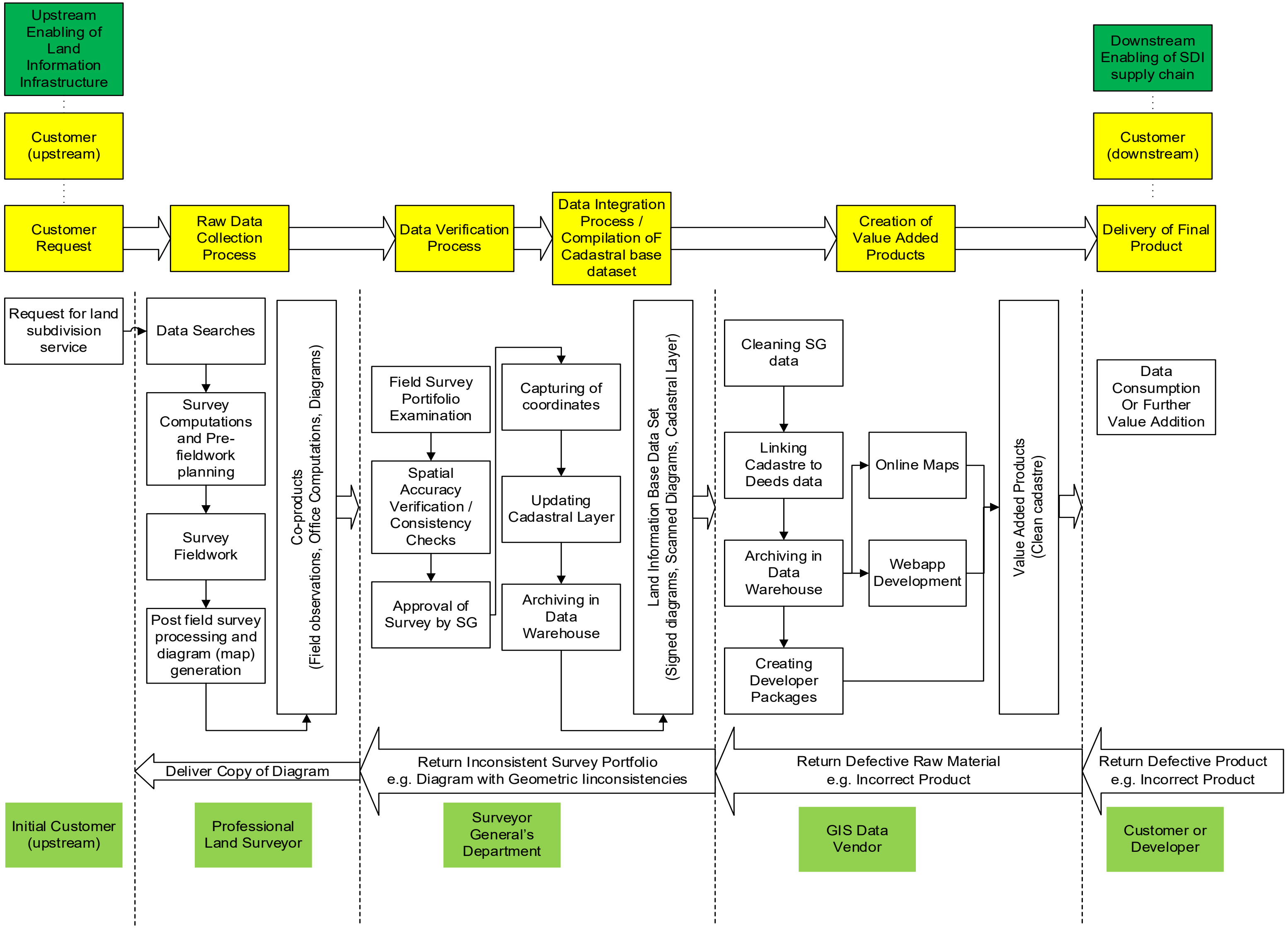

Figure 4: Workflow outlining the production processes of land information products and services

If the submitted survey does not meet the required accuracy standards, the Surveyor General's Office returns it to the professional land surveyor for correction as part of the verification process. The professional land surveyor resubmits the survey for verification after completing and correcting the noted inadequacies.

The geospatial data vendor sources the cadastral layer from the SG office as a raw material and adds value by creating generic and customised land information products and services for different customers. Some data sets merely go through a maintenance cycle so that they are always up-to-date and republished according to cycles stipulated by the data vendor. Maintenance cycles are crucial because data currency is an important attribute that gives value to spatial information. The final products eventually reach the end customer. The supply chain ends with downstream customers who consume the value-added products either as, amongst others, end users, developers, or value-added resellers, who may initiate other supply chains as an extension to the ones presented in Figures 4 and 5 to produce new land information products and services to different customers.

4.2. SCOR mapping of the land information infrastructure

In this section, level 2 mapping according to the SCOR model is presented in Figure 5. The land developer (initial upstream customer), who wishes to develop land into residential and commercial properties, requests a survey of the land (subdivision survey) from the land surveying firm, which is the supplier's supplier in the land information infrastructural supply chain. The land developer provides the professional land surveyor working for the land surveying firm with a subdivision layout and a subdivision permit (input: raw materials) approved by the municipality and showing the portion of land to be subdivided. The survey required by the land developer results in a general plan which is a make-to-order product. The land developer enables the supply chain since the downstream supply chain partners, such as the geospatial data vendor, depend on this general plan as the basic manufacturing component for further land information products and services that they wish to develop.

The land surveying firm is the supplier to the Surveyor General's Office. It is also a supplier to the land developer, responds to the requests of the land developer and undertakes field and office work which together result in the creation of a general plan as part of several make-to-order processes (sM2). The land surveying firm has to source information (sS1 – stocked land information products) from external sources to enable it to design the required general plan. The major external source is the Surveyor General's Office.

On completing the design of this general plan, this product needs to undergo a quality assurance process that is conducted in the Surveyor General's Office (the supplier) before it can be delivered to the land developer.

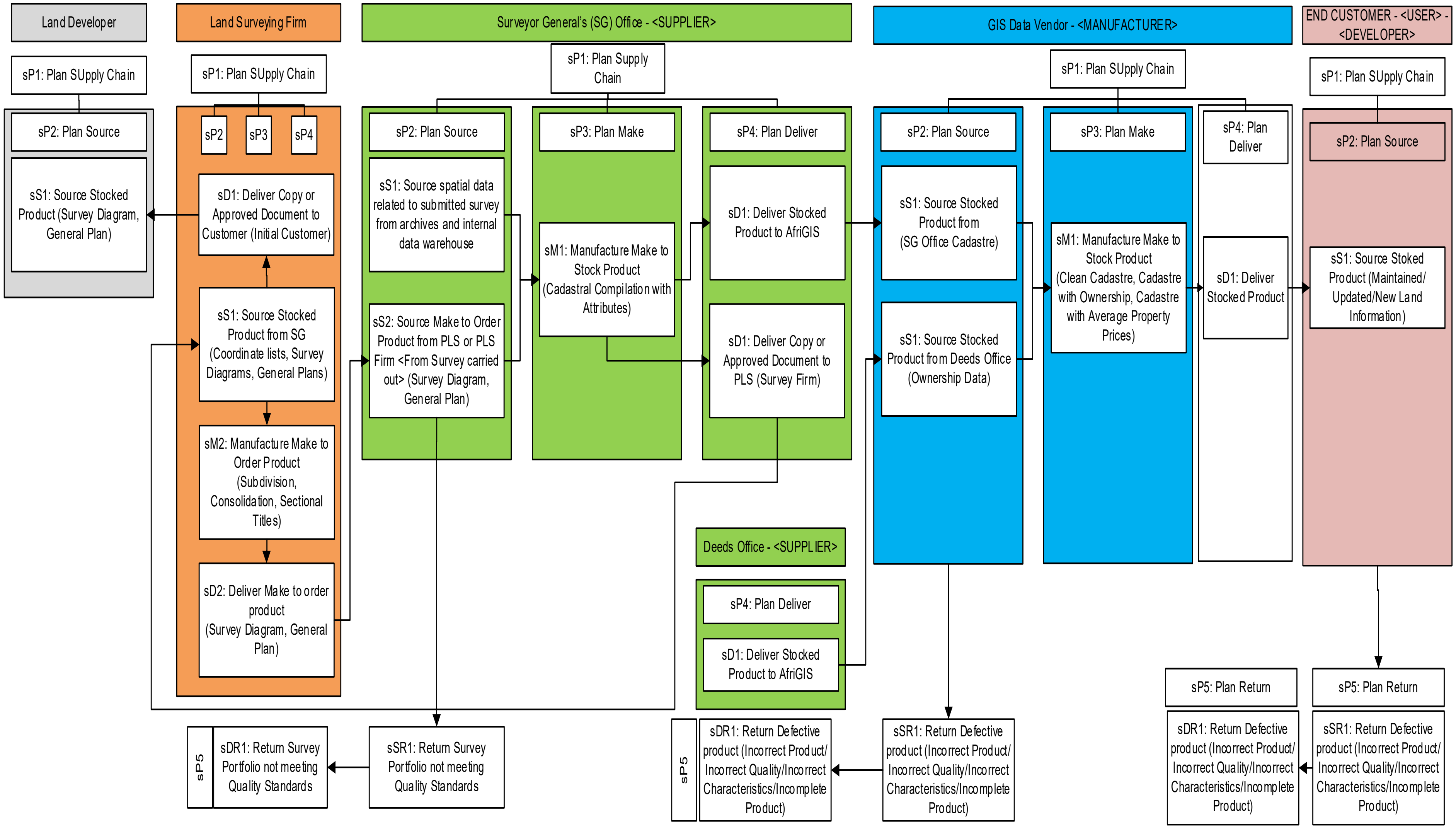

Figure 5: Level 2 SCOR mapping of land information infrastructure

The Surveyor General's department sources (sS2) the completed general plan (a make-to-order product) from the cadastral survey firm and examines it rigorously to ascertain that it conforms to the quality standards as per the Land Survey Act (No. 8 of 1997). If it conforms, the Surveyor General endorses the diagram to reflect this. A copy of the general plan is then delivered (sD1) to the land surveying firm as a stocked product which in turn delivers it to the land developer after securing payment for the plan.

Before construction commences, the land developer, who is the customer, proceeds to use this general plan to design plans for houses and shopping complexes through a third party. If the general plan does not meet the quality standards, it is returned to the surveyor for corrections as it is a defective product (sSR1). The endorsed general plan is a value-added land information product as it is a legal document that can be used to register new ownership on the portions of land presented. Upon the endorsement of the general plan, it is made available to other users who intend to create value-added land information products.

The geospatial data vendor, who is the manufacturer, sources input land information as a stocked product in the form of a collection of general plans from the Surveyor General's Office (sS1), which extracts this information from its data warehouse. The geospatial data vendor sources additional data from other suppliers, such as the Deeds Office, which provides information concerning property ownership, in order to fulfil the customer request by creating further value-added land information products.

The customer sources this product from the manufacturer (sS1) and uses it to solve a geographical problem. At each of these stages, if a customer is not satisfied with the product, he/she will return it to the supplier (sSR1). sDR1 denotes that a product has been delivered back to the manufacturer because it was found to be defective.

Within each stage of the land information infrastructure there is a flow of information about which the supply partners communicate. It is this information which is used to improve the quality of the product, its delivery and the associated customer service to the supply chain customers.

5. Discussion

In this paper, it was shown that a land information infrastructure can be mapped as a supply chain. Supply chains start upstream with suppliers of raw materials and end downstream with the customers, with a flow of products from upstream to downstream supply chain partners. The figures in the previous section illustrate that the land information infrastructure comprises downstream (source to product) and upstream (product to source) customers and/or end users. The upstream customers trigger the supply chain by kick-starting the production processes of raw materials required by the downstream customers. The upstream customers stimulate changes in the land information in the data warehouse at the Surveyor General's Office, the major raw material supplier for the wider land information infrastructure. The land information infrastructure comprises collaborating stakeholders in the production of value-added land information products that are delivered to customers as indicated in Cooper et al. (2019) in the context of spatial data infrastructures. This is consistent with the definitions of supply chains (Chopra and Meindl, 2013; Janvier-James, 2012). A land information infrastructure can therefore be viewed as a network of supply chains, focused on the production of land information. The production of value-added land information products through supply chains is analogous to value-adding in an information value stream (Krek and Frank, 2000; van Loenen and Zevenbergen, 2010). Mapping the stakeholders and the business processes in which they are involved improves the understanding of the operation of the land information infrastructure as supported by Chimhamhiwa (2010), who employed business process modelling for visualising the deeds delivery production line.

Mapping land information supply chains reveals the complexity of the land information infrastructure. This complexity is due to the size of the infrastructure, its evolving nature on account of the evolving land rights, uses and ownership, and changing user demands, as similarly noted in Williamson (2000); Steudler (2004); and van Oosterom et al. (2020). Not only are the processes mapped, but the organisations collaborating in the supply chain are revealed. Whether or not these organisations are aware that they are in fact in a supply chain, they should realise that they need each other in order to produce data sets and to serve their mandates, and the supply chain certainly shows this.

With this SCOR mapping, it is possible to re-engineer and fine-tune the land information infrastructure by effecting interventions for improving its effectiveness in delivering its products. For example, the turnaround time for the quality control process at the Surveyor General's Office could be improved by financing more information technology and hiring more staff. In this way, the finalised general plan is delivered more rapidly to the land surveying firm and the land developer. The interventions that improve the efficiency of land information infrastructures can only be established after mapping the SCOR level 3 process.

The SCOR mapping reveals the type of raw materials used in terms of stocked, make-to-order or engineer-to-order (sS1, sS2 or sS3), including the nature of the make or manufacturing (sM1 or sM2), delivery (sD1 or sD2) and return processes (sSR1 and sDR1) at each stage within the land information infrastructure. It is thus possible to trace a product and analyse how value is created at each stage in this supply chain. The same linkages can be used to trace information and monetary flows between parties or stakeholders in the supply chain.

While the land information infrastructure presented in this paper focuses on the production processes of land information, it plays a separate role in collecting customer feedback information on current product and service offerings. This makes the land information infrastructure more responsive to customer needs rather than for it to retain a static stance. The land information infrastructure should address changing information needs from its customers. This makes land information relevant for applications from different customers and as inputs to their decision-making processes. The organisations within the infrastructure should work collaboratively in creating new product lines as required by the customers.

Among the benefits of mapping the land information infrastructure using the SCOR model is the fact that the processes involved in the production of land information have been deciphered and presented using a standard supply chain language which can be interpreted by engineers and managers involved in monitoring the efficiency of the infrastructure in order to improve its effectiveness. With more detailed mapping (level 3 SCOR mapping), which is beyond the scope of this paper, it is possible to identify problem areas within the supply chain and to formulate corrective or improvement measures. Such corrective measures ensure that high-quality land information products and services are delivered to customers at the lowest possible cost and in the least amount of time. If this can be achieved, SCOR stands the chance of being successfully applied in managing the operational effectiveness of the land information infrastructure.

The supply chain mapping demonstrated in this study can be used to model and analyse business processes for the production of other land information products, such as as-built survey diagrams and thematic maps that are generated from spatial information infrastructures. The concepts presented in the SCOR model can be adapted to model supply chains of any network of organisations participating in the production and distribution of spatial data products and services.

The supply chain modelling presented in this article is static. It will evolve with time as technology transforms, new stakeholders emerge and customer needs change. Thus, as discussed in Badenhorst-Weiss and Nel (2011) and Celikbilek and Süer (2020), value streams need to be dynamic in order to continue providing value to customers. As land tenure representations evolve and new land rights and uses emerge (Williamson, 2000; van Oosterom et al., 2020), the business processes in the land information supply chain need to transform in order to develop new cadastral products as they are required.

The supply chain presented in this article does not represent the boundaries of the land information infrastructure but rather a snapshot of a portion of the infrastructure. The value stream in Figure 5 can be extended further to include the production of new cadastral information (e.g., another developer could buy a strip of properties from this subdivision, consolidate them into a single property and build apartments). Thus, the consolidation results in changes in the cadastre. When the apartments are sold to different owners, sectional titles are surveyed, thus producing new cadastral data.

6. Conclusions

The aim of this study was to apply supply chain mapping and the Supply Chain Operations Reference (SCOR) model to mapping and visualising a subset of the supply chain network in a land information infrastructure. The mapping revealed the processes and organisations involved in generating, testing, packaging and delivering land information, specifically cadastral data products, to end users. It further revealed that a land information supply chain is not a simple linear forward-facing chain, but a complex network of supply chains, some of which, on account of information reuse and the return of products, contain loops. This mapping contributes to a better understanding of a land information infrastructure.

The study confirmed that the production of land information products in a land information infrastructure can be viewed as a network of supply chains in which upstream and downstream partners interact to deliver value to their consumers. The operation of such supply chains can be monitored and managed. If and when necessary, it is possible for land information supply chains to be adjusted by the organisations constituting the land information infrastructure to address evolving user needs and land information processes. Using standard supply chain language makes the mapping accessible to engineers and managers with a background in supply chains. The modelling demonstrated in this study can be adapted to suit any supply chain for producing spatial information products. The models promote the ability to clarify and improve the performance of supply chains.

Future work entails level 3 SCOR mapping which will be used for performance management and the optimisation of the production processes of the land information products and services in the land information infrastructure.

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