

Track and Trace Future, Present, and Past Product and Money Flows with a Resource-Event-Agent Model

Abstract

This paper presents a reference model for the registration of economic data that enables the tracking and tracing of product and money flows in the registered data. The model is grounded in the REA ontology, which has its origin in accounting and provides the conceptual foundation for the ISO open-edition transaction standard. The use of the reference model is illustrated with an example database that demonstrates the different usage scenarios covered by the model.

Keywords

Reference Model, Traceability, Resource-Event-Agent Ontology, Money Flow, Product Flow, Business Transaction, Supply Chain Management

Introduction

Tracking and tracing are important notions in supply chain management. Tracking is defined as following a product's path through the supply chain from supplier to customer, and tracing as identifying a product's origin (Bechini, Cimino, Marcelloni, & Tomasi, 2008). Product traceability, which we use as an umbrella term for both tracking and tracing, can discourage free-rider behavior, such as providing substandard products, when product quality is capital (Pouliot & Sumner, 2008). That is why product traceability can be found in the pharmaceutical, automotive, aircraft industry and the agricultural and food sector (Wilson & Clarke, 1998). For example, in the aviation sector, aircraft parts are marked such that their lifecycle can be monitored carefully (Krizner, 2000).

Among these high-stake industries, the agricultural and food sector has been most visibly attributing attention to product traceability. Primarily because in the past, food borne, contagious diseases in livestock and food safety concerns for customers and their pets affected the credibility of food industry safety schemes. Bovine tuberculosis, foot and mouth, and BSE, which led to an EU ban on UK beef, revealed the need for a nationwide cattle tracing system (Calder & Marr, 1998; Folinas, Manikas, & Manos, 2006; Gilbert et al., 2005). Moreover, public health and safety concerns urge food traceability throughout its production process (Mousavi, Sarhadi, Fawcett, Bowles, & York, 2005). Additionally, potential bioterrorism raised interest in monitoring food chains (Gessner, Volonino, & Fish, 2007; Hartnett, Paoli, & Schaffner, 2009). Furthermore, retailers have found that commercial

advantage can be gained from certain aspects of source verification, which enables the marketing of raw materials (e.g., *appellation d'origine contrôlée*, *prosciutto di Parma*) (Moe, 1998; Pettitt, 2001).

Product traceability has been implemented in various ways, using a range of technologies. Some techniques are limited to the identification of a product's origin. For example, techniques for tracing the geographic origin of honey (Stanimirova et al., 2010) or beef (Bong et al., 2010). Other techniques also identify the product's path through the supply chain. Some of these approaches, like *gozinto* graphs (Jansen-Vullers, van Dorp, & Beulens, 2003), are limited to in-house traceability in production plants. Other approaches span parts of or whole supply chains from raw material to consumer, including production, transportation, packing, distribution, and processing (Moe, 1998; Ruiz-Garcia, Steinberger, & Rothmund, 2010). Many of these implementations use database and internet technology for monitoring transport processes, production processes, and setting up entire supply chain management systems. Mousavi et al. (2005; 2002) show a case for traceability in the meat processing industry. Houston (2001) addresses bovine traceability, where McGrann and Wiseman (2001) discuss international animal traceability and Gonzalez et al. (2010) present an approach for generic location tracking. Also a range of technologies, among which RFID (Jones, Clarke-Hill, Comfort, Hillier, & Shears, 2005), has been used to tag individuals products and batches. Hastein et al. (2001) present a range of technologies for traceability of aquatic animals.

Also other supply chains than the food chain can profit from cradle-to-grave supply chain monitoring (Welcome, 2009). Product traceability throughout the supply chain is needed for several reasons. First, important stakeholder groups may hold companies responsible for environmental and social impacts in their product chain, such as pollution, child labor, corruption, and discrimination (Hauschild, Dreyer, & Jørgensen, 2008; Norris, 2006). Second, supply chain intrusions such as counterfeit, which is a tool for criminal and terrorist organizations to finance their activities, negatively affect our economy (Dekieffer, 2007; Lowe, 2006) Third, commercial advantage can be gained from source verification and product quality assurance (Leat, Marr, & Ritchie, 1998; Moe, 1998; Viaene & Verbeke, 1998). Additionally, commercial advantage can be created by tracking and managing business transactions with customers and suppliers, as has been demonstrated for customer relationship management (Gessner & Volonino, 2005) and global supply chain optimization (Bassett & Gardner, 2010). Apart from the business intelligence that can be created by monitoring transactions with customers and suppliers, also business process intelligence, which is enabled by monitoring the own production process, can generate competitive advantage (Grigori et al., 2004).

Such cradle-to-grave, conscious- or eco-design (Hauschild, Jeswiet, & Alting, 2005; Zhang, Kuo, Lu, & Huang, 1997) and anti-counterfeit approaches to supply chain monitoring (Salgues & Bollampally,

2007) could also benefit from electronic data interchange registering the future paths of products. . McCormack (2001) shows that when business processes are designed to support the overall supply chain, the overall performance of an organization improves. However, the main problem today is that the information to implement such supply chain supporting business processes is scattered over various information systems including, in-house tracking and tracing systems as well as tracking and tracing systems for the entire supply chain.

Therefore, what is needed is a tracking and tracing reference model that can improve the information flow with partners inside and outside the enterprise from both the operational and planning perspective (Rabin, 2003). Such an improved information flow could be achieved through the creation or improvement of enterprise system interoperability, which would provide a unified view of business processes and functions to the partners that are involved in them (Mahato, Jain, & Balasubramanian, 2006). Mitigating the risk of under- or over-specifying¹ such a unified view, we derive the reference model from an existing conceptual model for intra- and inter-enterprise systems that already captures an (implicit) consensus regarding the representation of the domain and has established soundness (Kodaganallur & Sung, 2006).

This conceptual model is REA (McCarthy, 1982), which provides the scientific basis for the ISO-standardized open-edl business transaction ontology (OeBTO) (ISO/IEC, 2007). The REA ontology (Geerts & McCarthy, 2002) is based on the ideas of semantic data modeling (Chen, 1976) and was originally developed as a generalized accounting framework, in which accountants and non-accountants share data about the same set of business phenomena (McCarthy, 1982). REA has been used for modeling production processes (Hruby, 2006), supply chain management and e-collaboration systems (Haugen & McCarthy, 2000), enterprise information systems (Batra & Sin, 2008; Dunn, Cherrington, & Hollander, 2005), and management information systems (Church & Smith, 2008). Moreover, previous research has shown that REA can support the integration of business processes across enterprise boundaries (Gailly, Laurier, & Poels, 2008). Therefore, REA cannot be considered an accounting-only ontology. However, because of its accounting roots (Gal & McCarthy, 1986; Hollander, Denna, & Cherrington, 1999; McCarthy, 1979), REA incorporates the accounting discipline's more than 500 years of practical experience in recording business transactions. REA is, to the best of our knowledge, the only conceptual model that supports at the same time the registration of past, current and future (e.g., accounts receivable) money flows, next to the registration of product flows, and it does so for flows within and between enterprises.

¹ Under-specifying would be creating a solution that can only track car parts, over-specifying would be creating a solution that also tracks address changes of employees.

Next to building a reference model for tracking and tracing, this paper presents a prototype application that is based on the model. This prototype application evaluates the model in a Design Science tradition (Hevner, March, Jinsoo, & Ram, 2004). Since the reference model presents a new kind of data model, it cannot be compared with existing models, nor can existing data logs be used to prove its utility. The reference model could be evaluated through the actual implementation of an information system that supports both the overall supply chain and the individual business processes of the supply chain partners. However, such an implementation involves many challenges² that would distract the attention from the contribution this paper aims to make. Therefore, descriptive scenarios are used to demonstrate the utility of the reference model (Feather, Fickas, Finkelstein, & van Lamsweerde, 1997; March & Smith, 1995). These descriptive scenarios suggest a reality check of the proposed reference model by providing a comprehensive and concise representation of the problem at a sufficient level of complexity. As our research artifact is novel, descriptive scenario's provide the highest level of evaluation achievable at this stage of development (Hevner, et al., 2004). The descriptive scenarios are executed through the prototype application which demonstrates that the proposed reference model can be used to represent both production processes and transactions between trading partners, while abstracting from issues such as sensitive information and privacy protection.

Section 2 presents the new reference model for tracking and tracing and explains how it was developed from REA. Subsequently, section 3 presents the descriptive scenarios of using the reference model via a prototype application. Finally, Section 4 presents conclusions and directions for future research.

Reference Model for Tracking and Tracing

The conceptual model that we propose for recording inter- and intra-enterprise phenomena is shown in Figure 1, where it is represented as a class diagram. Many of the concepts and relations in the

² The implementation of a supply chain monitoring system requires the cooperation of each supply chain partner. Since supply chain partners have both parallel and opposing interests (Brandenburger & Nalebuff, 1996), access to 'strategic' information has to be limited. For example, for a supplier it is most probably undesirable to provide a customer access to data that allow the customer to estimate the actual production cost of a product and hence also the supplier's profit margin. However, in the case of vendor managed inventory (VMI) a customer may want to provide its supplier information about stock levels where competitors cannot have access to this information. Also information about an enterprise's cash supplies needs to be protected. Such 'strategic' and safety requirements, among which the protection of strategic information and privacy (Garita, Afsarmanesh, & Hertzberger, 2001; Jones, et al., 2005; Jung, Chen, & Jeong, 2008; Liu & Bailey, 2009; Sheng, Xue, & Zeadally, 2008), considerably augment the complexity and hence cost of building a pilot application in a real-world setting.

model are taken from the REA ontology. In this section, we present these concepts and relations and explain how they were used to build a reference model for tracking and tracing future, past, and present money and product flows.

The *economic agent* class is used for representing natural persons that act on behalf of legal persons (ISO/IEC, 2007), which are represented themselves using the organizational unit class. The concept of *organizational unit* refers to the passive role of a person as an owner or possessor of economic resources (confer infra). This means that organizational units have economic *control* over resources, which gives them ownership of the right to derive economic benefit from a resource and entails the discretionary power to use or dispose of these resources via economic events (confer infra) in a legal way. The economic agent construct, on the other hand, represents the active role of a person as a performer of economic events (McCarthy, 1982). Organizational units represent the entities that experience the effect of events, whereas agents represent the entities that engage in events. For example, an employee performs an event that affects his employer's resources. So agents may have access to resources of which they are not the owner, which means that they have custody but not economic control over the resources and that in that case the agents act on behalf of organizational units. For example, an employee is an agent for its employer, as the employee performs tasks from which the employer reaps the full benefits.

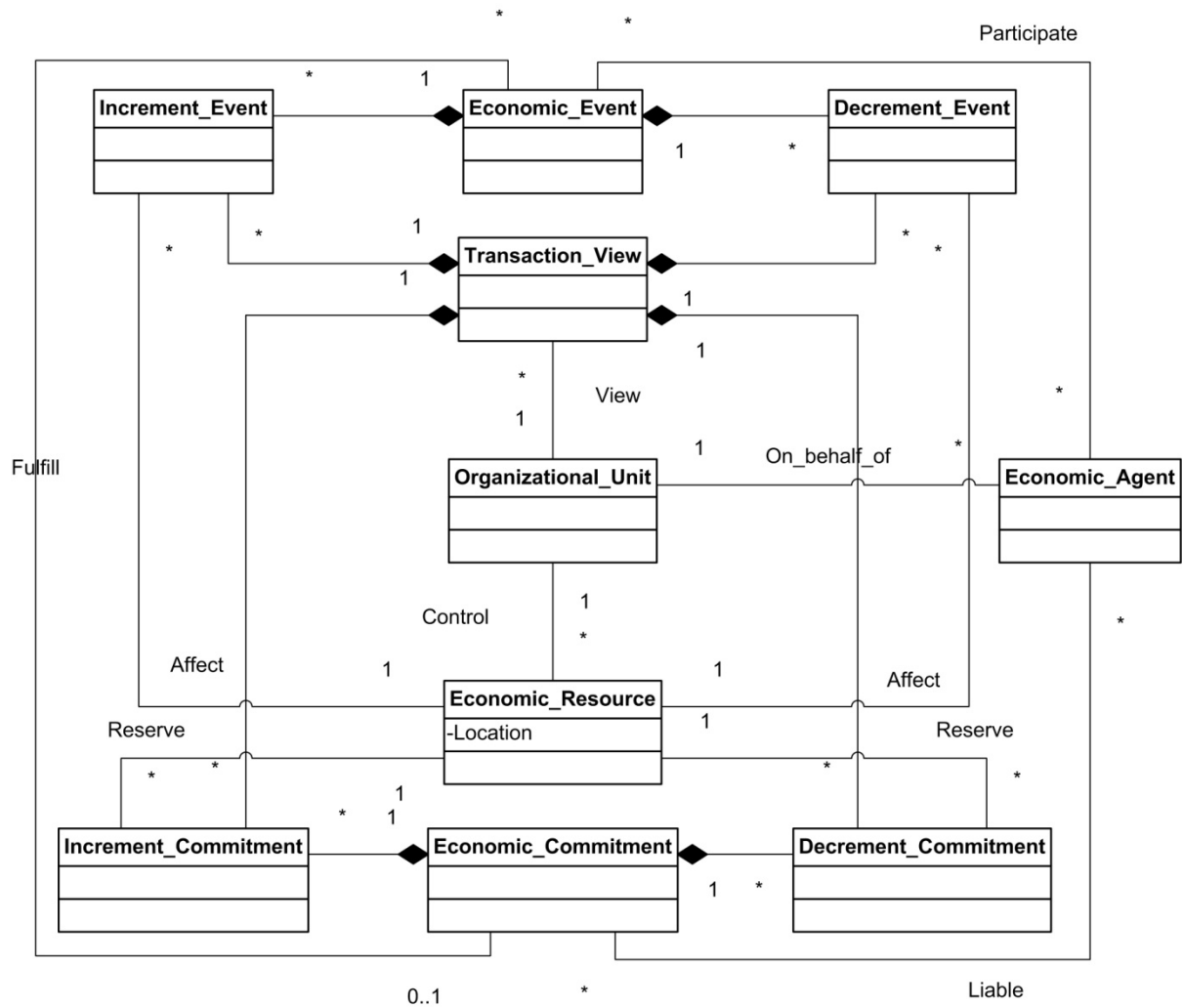


Figure 1. Tracking and Tracing Conceptual Data Model Structure

The *economic resource* class represents objects, such as rights, goods and services, that are scarce, have utility and are under the control of an organizational unit, such as an enterprise or household (Ijiri, 1975; ISO/IEC, 2007; McCarthy, 1982). The scarceness indicates that not every organizational unit can control such resources at a certain point in time and indicates that for some organizational units trade is required to gain control over particular resources. The utility motivates why certain organizational units want to gain control over particular resources. The *economic event* class represents the events, such as produce, exchange, consume and distribute events, that *affect* economic resources in the sense that they increase or decrease resource stocks (Yu, 1976). The recognition of both sides of an economic event (i.e., *increment event* for a resource increase and *decrement event* for a resource decrease) is a unique feature of the reference model for tracking and tracing presented here. It acknowledges that a single event can be perceived both as an increment and a decrement event by trading partners. For example, a product shipment can be perceived as an increment by the buyer, who receives the product, and a decrement by the seller, who dispatches

the product. As will be explained further on in the paper, this two-sided view of economic events is a key element in our solution for modeling inter- and intra-enterprise phenomena.

Not present in the REA ontology is the *transaction view* class, which we use to aggregate event perceptions in order to satisfy the REA ontology axiom³ that requires that from the perspective of each trading partner, every decrement event must be eventually paired with one or more increment events, and vice versa (Geerts & McCarthy, 2004; Ijiri, 1975). This REA axiom defines equitable trades. For example, in market transactions this economic reciprocity dictates that when a company sells products to a customer, a requiting event like a payment or delivery of equally or higher valued goods by the customer must follow. This payment or delivery has to compensate for the decreased value of the company's inventory of products, which is caused by the sale, by increasing the value of the company's inventory of money or products in case of barter trade.

Next to economic events, the REA ontology addresses commitments, which are represented by the *economic commitment* class and represent the promise to perform economic events in the future. Consequently, the conceptual model also addresses data that describe future economic events, next to data created by past and current events. Since commitments represent future events the commitment structure replicates the event structure. Like an event, a single commitment can be perceived as an increment by one trading partner and a decrement by another trading partner. For example, a buyer promises to pay a seller within 30 days after goods delivery. The seller perceives this as an increment since it adds to accounts receivable. The buyer perceives this as a decrement as it adds to accounts payable. Like agents can participate in economic events, they can also be liable for commitments, and like resources can be affected by economic events, they can also be reserved for the fulfillment of commitments. Eventually, a commitment will be fulfilled by one or more events. A transaction view taken by an organizational unit may also aggregate reciprocal commitment perceptions, which balance increment and decrement commitments, just as it aggregates dual event perceptions.

Figure 2 shows an example event-driven process chain (EPC) that documents a business transaction's flow of events, their resource inputs and outputs, and the involved agents and organizational units. The example EPC model shows the exchange of pizza for money between the organizational units Pizza Luigi and John. The pizza transfer is perceived as a decrement by Pizza Luigi and as an increment by John, while the transfer event is participated in by the agents Luigi and John, the latter

³ The REA ontology axioms stem from basic laws of business (e.g., economic reciprocity) and describe the invariant conditions of the business domain as well as prescribe the permissible range of variation in conceptual models for that business domain (Fonseca & Martin, 2007).

of which can be seen as acting on behalf of himself. The remunerating money transfer, on the other hand, is perceived as an increment by Pizza Luigi and as a decrement by John. Like the pizza transfer, the money transfer event is participated in by Luigi and John. The transaction views then connect the opposing transfers. From Pizza Luigi's point of view, which is represented by a first transaction view, a pizza decrement is paired in duality with a money increment. From John's point of view, which is represented by a second transaction view, a pizza increment is paired in duality with a money decrement. Both trading partners perceive the exchange as complete when both transfers have been completed as agreed.

It should be noted that our REA-based reference model for tracking and tracing (figure 1) does not impose the sequence of events. Therefore, the product and money transfers in the EPC model are executed in parallel, i.e. independently from each other, which means that they are allowed to happen simultaneously or in any sequence. However, when in particular circumstances a strict sequence of events is required (e.g. pay before product delivery), the EPC model can be used to indicate these sequence constraints.

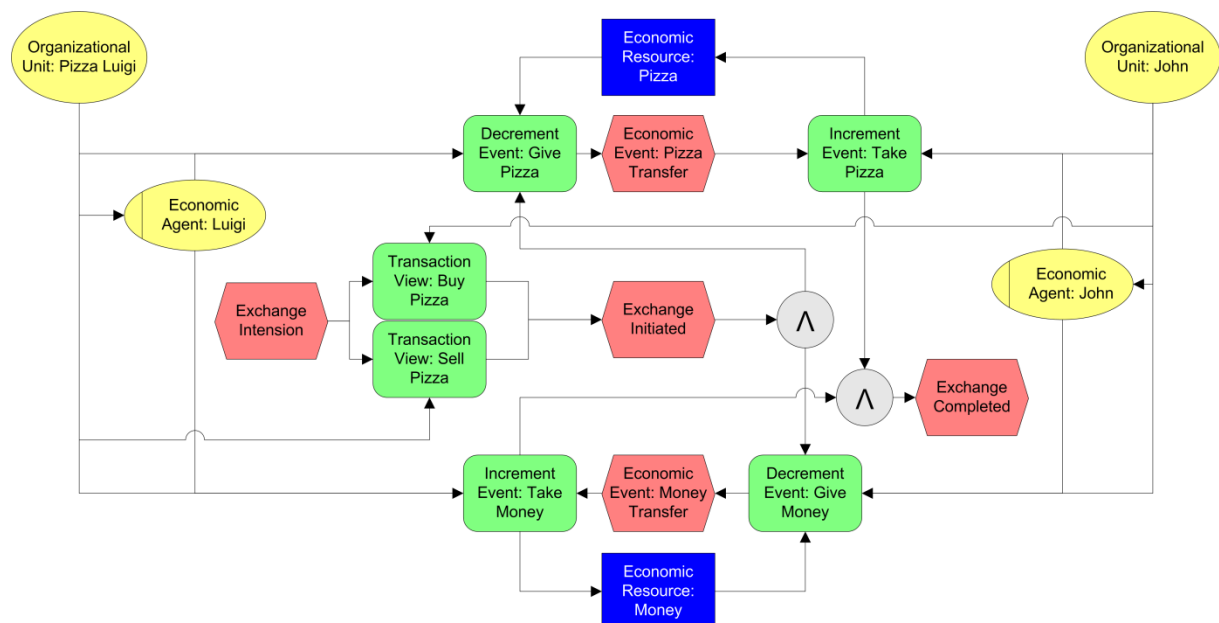


Figure 2. Exchange model with two mirrored transfer events

The exchange model in fig. 2 contains both the view of the buyer and the seller, integrating the acquisition and providing behavioral pattern in the product traceability reference model of Bechini et al. (2008). This integration eliminates redundant data, since the same product transfer is recorded twice (i.e., once as a providing and once as an acquisition pattern) when we use Bechini et al.'s model, where it is only recorded once with our model. Moreover, the explicit representation of the increment and decrement perspective on economic events eliminates the need for pre- and post-

acquisition and pre- and post providing lots⁴, since they can be identified as the same resource that is affected differently depending on the perspective taken with the REA-based data model. These unifications should facilitate the sharing of business transaction data between trading partners and eliminate data redundancy and inconsistencies when sharing business transaction data.

An interesting feature of the model in Figure 1 is that it can also be used to represent transformations. These transformations include integrations, which consume multiple inputs to produce an output, divisions, which consume an input to produce multiple outputs, alterations, which convert one input in another output, and movements, which transport a resource to another location (Bechini, et al., 2008). Figure 3, for instance, shows the process of baking pizza, which converts ingredients to pizza. The model represents the consumption of pizza ingredients (i.e., yeast, water, flour, hamburger meat and tomatoes) as decrement events that correspond to the stock decreases caused by the pizza production event as perceived by Pizza Luigi. The production of the pizza, on the other hand, is perceived as a stock increase by Pizza Luigi. Consequently, the production is modeled as an increment event. Figure 3 also shows that the pizza production event is performed by Luigi and that the pizza baking transaction causes both increases and decreases of Pizza Luigi's stocks. This means that a same economic event can also be perceived as both increment and decrement by the same organizational unit. When representing a conversion process, the transaction view compensates the loss of process inputs with outputs of equal or higher value, where the economic events represent the swap of inputs for outputs in each production step. The transaction is perceived as complete by Pizza Luigi when the inputs have been replaced by the desired outputs.

Subsequently, Figure 4 shows the transport of a pizza as part of its conversion process. The model represents the removal of the pizza from one location and the delivery at another location. The transaction is perceived as complete by Pizza Luigi when the goods that were removed from one location are deposited at another location.

⁴ In Bechini et al.'s model, a *pre-acquisition* lot is the image of a product before the sale occurs from the perspective of the buyer. A *post-acquisition* lot, on the other hand, is the image of that same product after the sale has occurred from the perspective of the buyer. A *pre-providing* lot then represent the same product before the sale occurs from the perspective of the seller, where the *post-providing* lot then represents the same product after the sale has occurred from the perspective of the seller.

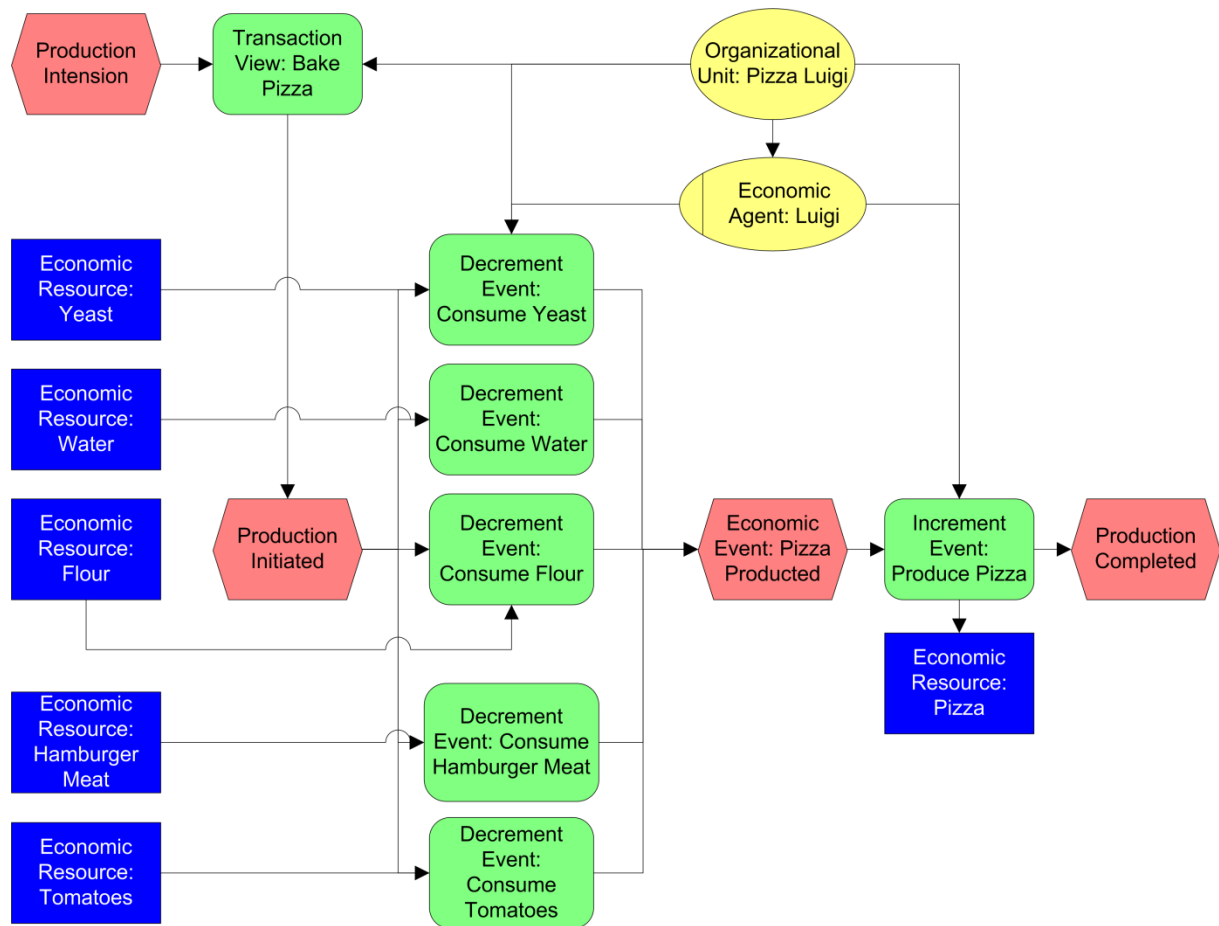


Figure 3. Conversion model with one transformation event

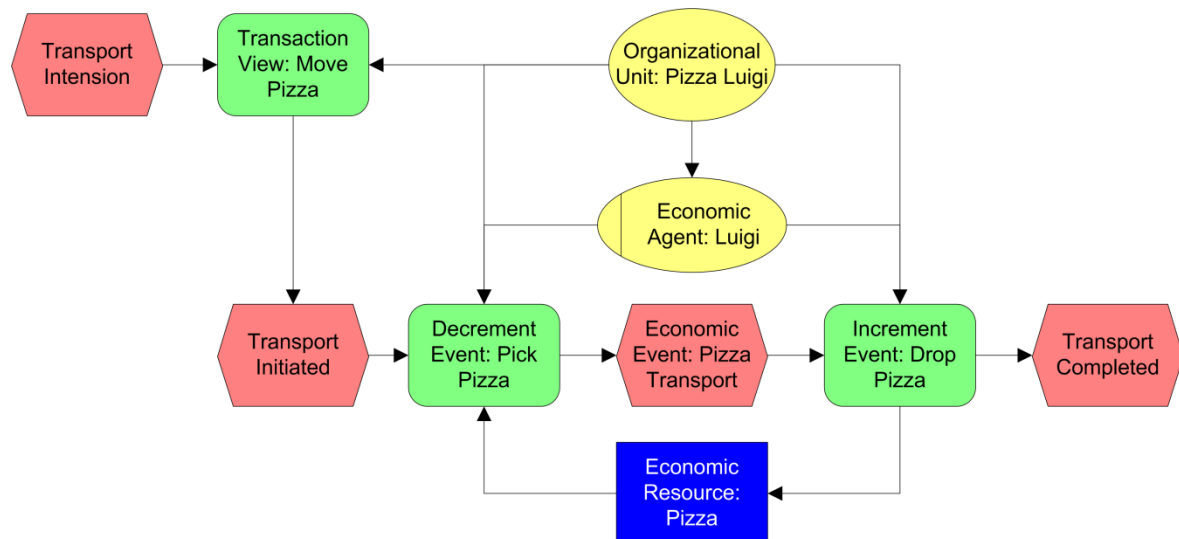


Figure 4. Conversion model with one transportation event

To complete the example, Figure 5 shows the fulfillment of a commitment to make bread. Such a connection between a commitment (e.g. a production order) and the event that fulfills it can already be observed in the product traceability reference model proposed by Jansen-Vullers et al. (2003)

However, the scope of that model is limited to the production processes of a single enterprise. Figure 5 reveals that the commitment to make bread is fulfilled by two subsequent events (i.e., make dough, bake bread). The commitment to make bread is represented as the committed conversion of ingredients in bread. It is fulfilled by the process of converting ingredients into dough and dough into baked bread. Like the pizza production event in the other transformation template (Figure 3), the events and commitments belong to the same conversion cycle, which is represented as a transaction view. The commitments then prescribe the conditions that need to be satisfied by the business process to complete the transaction from Baker Chet's perspective.

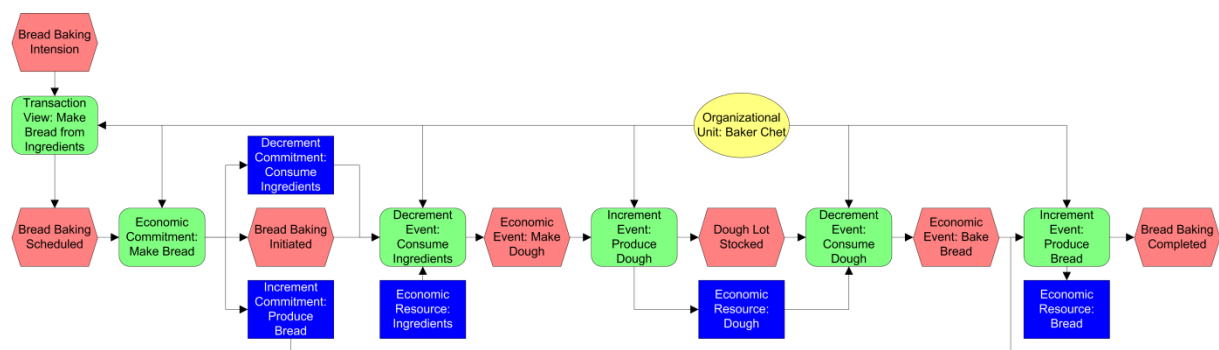


Figure 5. Bread baking commitment

Next to representing the fulfillment of commitments, figure 5 also shows subsequent events in the business process (i.e., make dough precedes bake bread). When increment and decrement events affect the same lot, batch or item, they represent an event sequence in a product trace. Such an event sequence satisfies the REA axiom that requires that every economic event must affect identifiable resources (e.g. lot, batch, item) and that an increment and decrement event have to be identified for each of these resources (Geerts & McCarthy, 2004).

Subsequent events in an event chain share the organizational unit that perceives them and the resource they affect. More precisely, the preceding event in the chain produces an item or batch, which increases the resource stock, the following event consumes that item or batch, which decreases the resource stock. In the case of services, the consume and produce event are simultaneous, which makes the resource stock intangible. In the case of continuous processes, event timestamps can be used to delimit virtual batches. For example, when all dough is stored in one trough and no dough lots are identified, dough that is taken from a trough before contaminated dough is added to that trough cannot be contaminated.

The preceding EPC models illustrate how the model of Figure 1 can be used to register the data for transactions between business partners, conversion processes and commitments. Exchange and

conversion models allow us to identify the resource batches/items that are affected by transfer, transformation and transportation events and subsequent events can be identified through their perception (i.e., increment or decrement) by the organizational units that control the resource batches/items they affect. This allows us to construct event chains that span multiple organizational units. Such chains can then be used to track and trace product and money flows through transfers, transportations and transformations. The event notion enables the registration of past and current product and money flows, while the commitment notion enables the registration of future product and money flows. Finally, REA's fulfillment notion maps what happened in reality to what was originally committed.

Prototype Application: Baking Bread and Pizza, From Farm to Customer

In this section, we discuss a prototype application that illustrates the possibilities for tracking and tracing offered by the reference model presented in the previous section (Figure 1). The application concerns a food supply chain (Figure 6) that starts with cattle and corn farmers and ends with consumers that buy and consume pizza and bread. The supply chain also contains a flour mill, which transforms wheat into flour, a grinder, which transforms corn and grain into cattle feed, a butcher, which transforms cattle into hamburger meat, a grocer, which provides groceries to a baker and a pizza restaurant, a baker, which transforms flour and other ingredients into bread that is sold to customers, and a pizza restaurant, which converts flour, hamburger meat and other ingredients into pizza that is sold to customers. The data model of the application, constructed using our reference model, is shown in Figure 7. A Microsoft Access database that is based on this data model and is populated with example registrations is available on-line (<http://www.managementinformatics.ugent.be/Traceability.accdb>).

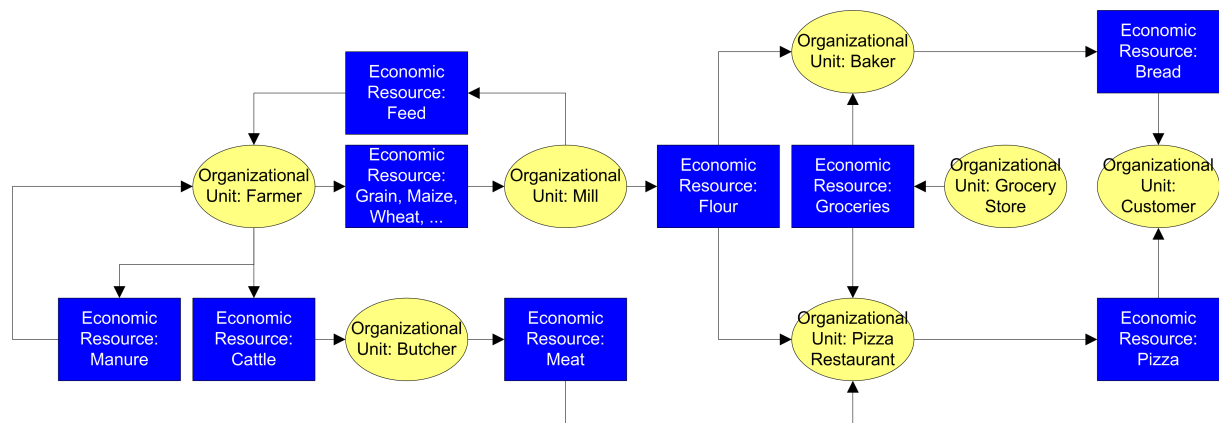


Figure 6 Example food supply chain

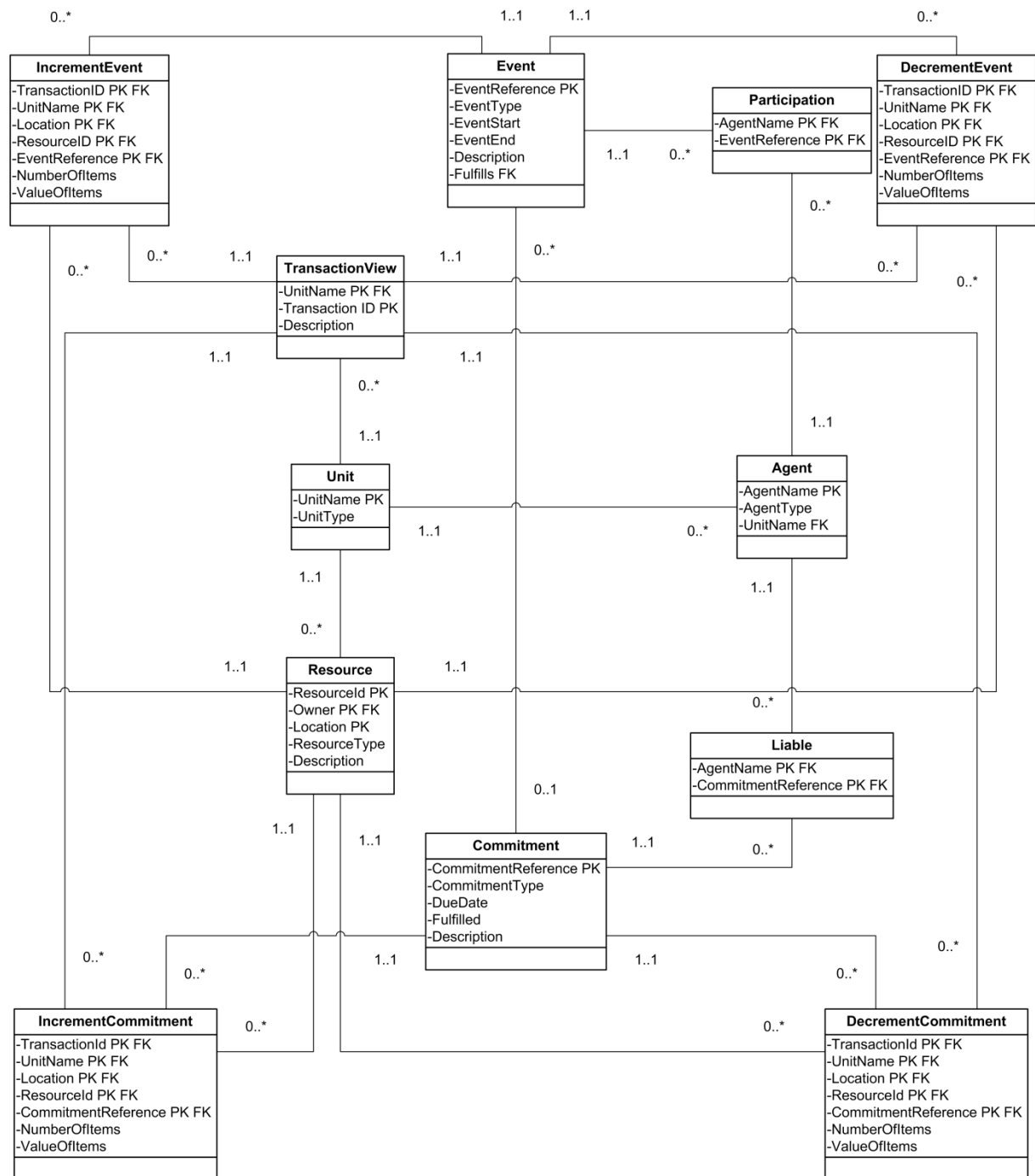


Figure 7 Application data model for traceability

Figure 8 shows some example event summaries that were extracted from the application's database by joining and querying the Event, IncrementEvent, and DecrementEvent tables. The event data in the provider, from, and input columns originate in the DecrementEvent table, through the foreign keys UnitName, Location, and ResourceId. The event data in the output, to, and recipient columns originate in the IncrementEvent table, through the foreign keys ResourceId, Location, and UnitName.

With the data contained in an event summary, we can distinguish transfer, transformation, and transportation events. Transfers are events of which the increment side is perceived by one organizational unit (i.e., the recipient) and the decrement side is perceived by another organizational unit (i.e., the provider), while the resource that is affected by the event does not change form or substance (e.g., event25)(Geerts & McCarthy, 2004). Transformations, on the other hand, are events of which the increment and decrement side is perceived by the same organizational unit, while the resources that are affected by the increment (i.e., output) and decrement side (i.e., input) differ as they change form or substance (e.g., event01). Finally, transportations are events of which the increment and decrement side is perceived by the same organizational unit, while the resource that is affected changes location, as 'from' is different from 'to', but not form or substance (e.g., event00). The event summaries thus indicate resource ownership changes with provider-recipient semantics, resource location changes with from-to semantics, and resource form or substance changes with input-output semantics. Hence, the optional EventType attribute of the Event entity type in the data model (Figure 7) is a derived attribute, which was added to the event summary for the sake of clarity.

EventRefer	Provider	From	Input	OutPut	To	Recipient	EventType
Event00	Grain Farmer	Dunghill	Manure	Manure	Field	Grain Farmer	Transportation
Event01	Grain Farmer	Field	Manure	Grain	Field	Grain Farmer	Transformation
Event09	Flour Mill	Warehouse	Wheat	Lot 1	Warehou	Flour Mill	Transformation
Event15	Butcher Pete	Cowshed	Daisy	Lot B	Fridge	Butcher Pete	Transformation
Event15	Butcher Pete	Cowshed	Daisy	Lot D	Warehou	Butcher Pete	Transformation
Event16	Baker Chet	Warehouse	Lot 1	Lot A1	Warehou	Baker Chet	Transformation
Event16	Baker Chet	Well	Water	Lot A1	Warehou	Baker Chet	Transformation
Event16	Baker Chet	Warehouse	Yeast	Lot A1	Warehou	Baker Chet	Transformation
Event17	Pizza Luigi	Warehouse	Yeast	Lot B1	Kitchen	Pizza Luigi	Transformation
Event17	Pizza Luigi	Warehouse	Lot 1	Lot B1	Kitchen	Pizza Luigi	Transformation
Event17	Pizza Luigi	Fridge	Lot A	Lot B1	Kitchen	Pizza Luigi	Transformation
Event17	Pizza Luigi	Warehouse	Tomatoes	Lot B1	Kitchen	Pizza Luigi	Transformation
Event17	Pizza Luigi	Well	Water	Lot B1	Kitchen	Pizza Luigi	Transformation
Event18	Tom	Kitchen	Lot A1	Utility	Home	Tom	Transformation
Event19	Dick	Kitchen	Lot A1	Utility	Home	Dick	Transformation
Event21	Harry	Kitchen	Lot B1	Utility	Home	Harry	Transformation
Event22	Cattle Farmer	Dunghill	Fresh Man	Fresh Man	Dunghill	Grain Farmer	Transfer
Event22M	Grain Farmer	Bank	Money	Money	Bank	Cattle Farmer	Transfer
Event25	Grain Farmer	Field	Grain	Grain	Field	Grinder's	Transfer
Event33	Flour Mill	Warehouse	Lot 1	Lot 1	Warehou	Baker Chet	Transfer
Event35	Flour Mill	Warehouse	Lot 1	Lot 1	Warehou	Pizza Luigi	Transfer
Event41	Baker Chet	Warehouse	Lot A1	Lot A1	Kitchen	Tom	Transfer
Event42	Baker Chet	Warehouse	Lot A1	Lot A1	Kitchen	Tom	Transfer
Event43	Baker Chet	Warehouse	Lot A1	Lot A1	Kitchen	Dick	Transfer
Event44	Pizza Luigi	Kitchen	Lot B1	Lot B1	Kitchen	Dick	Transfer
Event45	Pizza Luigi	Kitchen	Lot B1	Lot B1	Kitchen	Harry	Transfer

Figure 8 Event summaries

Another database view that can be taken shows transaction summaries (Figure 9). This view is obtained by joining and querying the TransactionView, IncrementEvent, DecrementEvent,

IncrementCommitment, and DecrementCommitment tables. The transaction identification and unit name are found in the TransactionView table. For each transaction view, which is identified through a unique combination of transaction identification and unit name, all related event or commitment records, in respectively the IncrementEvent, DecrementEvent, and IncrementCommitment, DecrementCommitment tables, are selected. For each of these records, the event or commitment reference is included in the transaction summary, as well as the number and value of the items involved in the event or commitment. Also the affected resources are identified, either as outflows for decrement events or commitments or inflows for increment events and commitments. The value of the resources involved allows determining whether a transaction is (expected to be) value adding from the perspective of an organizational unit.

If the transaction is an exchange, the transaction is perceived by trading partners with opposing views. In Figure 9, we see that there are two views of transaction 22. For the cattle farmer, transaction 22 consists of a fresh manure outflow and a money inflow, where it consists of a fresh manure inflow and a money outflow for the grain farmer. Although these two transaction views share the same events (i.e., event22 and event22M), these events are perceived differently by the trading partners, as the money inflow for the cattle farmer and the money outflow for the grain farmer are the same transfer event (i.e., event22M) and the fresh manure inflow for the grain farmer and the fresh manure outflow for the cattle farmer are also recognized as the same transfer event (i.e., event22). If the transaction is a conversion, then there is only one transaction view, which shows the perception of the single organizational unit performing the conversion and the resource inflows and outflows that are involved in the conversion process. For example, transaction 17 shows that lot B1 is produced by consuming water, yeast, tomatoes, lot A, and lot 1.

Transaction	UnitName	EventReference	CommitmentReference	Outflow	Inflow	NumberOfItems	ValueOfItems
Transaction17	Pizza Luigi	Event17			Lot B1	2	100
Transaction17	Pizza Luigi	Event17		Yeast		50	25
Transaction17	Pizza Luigi	Event17		Water		1	0
Transaction17	Pizza Luigi	Event17		Tomatoes		5	10
Transaction17	Pizza Luigi	Event17		Lot A		1	20
Transaction17	Pizza Luigi	Event17		Lot 1		2	4
Transaction22	Cattle Farmer	Event22		Fresh Manure		20	20
Transaction22	Cattle Farmer	Event22M			Money	0	20
Transaction22	Grain Farmer	Event22			Fresh Manure	20	20
Transaction22	Grain Farmer	Event22M		Money		0	20

Figure 9. Transaction summaries

The event and transaction summaries provide the basic elements to construct product and money tracks and traces and to reveal their mutual dependency. The event summaries provide the

information to construct product and money tracks and traces, whereas the transaction summaries show the dependencies between product and money flows.

Figure 10 is a view that shows the resource traces that reveal the production history and origin of products. It shows, for instance, that lot BB originates in grain and maize, which both originate in manure and have not been partitioned in smaller lots. To construct a resource trace, as shown in Figure 10, we identify all inputs of the event(s) that produced the resource. For each of these inputs, we repeat the process and identify the inputs that lead to their production. This process is repeated until the desired length of the resource trace is achieved. To construct a resource track, we identify all outputs for which a particular resource was an input. For each of these outputs we repeat this process and identify the outputs for which they were inputs. This process is repeated until the desired length of the resource track is achieved. As resources do not change form or substance during transfer and transportation events, we can abstract from these kinds of events for the construction of resource tracks and traces.

Furthermore, event tracks and traces, which show the sequence of events that lead to the creation of a product, can be constructed. Two sequential events are identified by the fact that they affect the same resource (e.g., item, lot or batch) at the same location, controlled by the same organizational unit. The former event is recognized as an increment (e.g., produce, take) to the affected resource stock, the latter event is recognized as a decrement (e.g., consume, give) to the affected resource stock. Since every event is perceived as increment and decrement by the same organizational unit (in case of transformations and transportations) or different organizational units (in case of transfers), preceding and following events can be identified and added to the event chain until it attains the desired length. Event traces identify the chain of events (i.e., transfer, transformation and transportations) that preceded a particular event, whereas event tracks identify the chain of events that followed a certain event.

Figure 11 shows such an event track. It shows that event 11 is not followed by any event, where event 9 is followed by events 33, 35, 17, 16, 41, 42, 43, 44, 45, 18, 19 and 21. Events 9, 16, 17, 18, 19 and 21 represent transformation events (see the event summaries in Figure 8), where events 33, 35, 41, 42, 43, 44 and 45 represent transfer events (see the event summaries in Figure 8). Together, these events create 5 different paths that originate in event 9. Similar to event tracks and traces for product flows, event tracks and traces for money flows can be constructed. Since money does not change form or substance, the construction of resource tracks and traces for money is superfluous.

Event tracks allow producers to follow their products throughout the supply chain, which enables the discrimination of proper and improper product use. For example, the event track that starts with

event 9 allows the flour mill to follow the use of its flour. Event 9, which represents the production of lot 1 (i.e., flour) from wheat by the flour mill, is followed by events 35 and 33. Event 33, which represents transferring part of lot 1 from the flour mill to Baker Chet (see the event summaries in Figure 8), is followed by event 16. Event 35, which represents transferring part of lot 1 from the flour mill to Pizza Luigi (see the event summaries in Figure 8), is followed by event 17. Event 16, which represents the production of lot A1 (i.e., bread) by Baker Chet (see the event summaries in Figure 8), is followed by events 41, 42 and 43. Event 17, which represents the production of lot B1 (i.e., pizza) by Pizza Luigi (see the event summaries in Figure 8), is followed by events 44 and 45. Consequently, the flour from lot 1 has been used to produce pizza and bread. Events 41, 42 and 43 represent selling bread from lot A1 to Tom, Tom and Dick respectively (see the event summaries in Figure 8). Events 44 and 45 represent selling pizza from lot B1 to Dick and Harry respectively (see the event summaries in Figure 8). Events 18 and 19 then show the consumption of bread by Tom and Dick (see the event summaries in Figure 8), where event 21 shows the consumption of pizza by and Harry (see the event summaries in Figure 8). Since event 44 has not been followed by a consuming event, Dick did not consume his pizza yet. If, for example, Harry is diagnosed with a food borne illness, and the origin is traced back to the flour mill, Dick can be warned not to consume his pizza. Although it might be impractical to register the consumption of resources by consumers, the example illustrates the expressive power of the data model.

Where a flour contamination can also be retrieved and treated with resource traces and tracks, the more advanced event traceability provides more information about the operations that were performed on a product. Such information might be crucial when proper product treatment is crucial to guarantee product quality. For example, in a cold chain, food is guaranteed to preserve its quality when the chain is not broken (i.e., when the temperature never exceeds a certain level). Meat is a product that requires a cold chain to preserve its quality. The event summary of event15 in Figure 8 shows that lot D (i.e., steak, see the Resource table in the database) is stored in the warehouse instead of the fridge. Consequently, the cold chain is broken and the quality of lot D cannot be guaranteed. From the participation table in the database we can derive that Jim can be held accountable for this 'mistake'.

TraceRoot	T1	T2	T3	T4	T5
Lot AA	Grain	Manure			
Lot AA	Maize	Manure			
Lot B	Daisy	Lot AA	Grain	Manure	
Lot B	Daisy	Lot AA	Maize	Manure	
Lot B	Daisy	Lot BB	Grain	Manure	
Lot B	Daisy	Lot BB	Maize	Manure	
Lot B1	Lot 1	Wheat	Manure		
Lot B1	Lot A	Bella	Lot AA	Grain	Manure
Lot B1	Lot A	Bella	Lot AA	Maize	Manure
Lot B1	Lot A	Bella	Lot BB	Grain	Manure
Lot B1	Lot A	Bella	Lot BB	Maize	Manure
Lot B1	Tomatoes				
Lot B1	Water				
Lot B1	Yeast				
Lot BB	Grain	Manure			
Lot BB	Maize	Manure			
Lot C	Bella	Lot AA	Grain	Manure	
Lot C	Bella	Lot AA	Maize	Manure	
Lot C	Bella	Lot BB	Grain	Manure	
Lot C	Bella	Lot BB	Maize	Manure	
Lot D	Daisy	Lot AA	Grain	Manure	
Lot D	Daisy	Lot AA	Maize	Manure	
Lot D	Daisy	Lot BB	Grain	Manure	
Lot D	Daisy	Lot BB	Maize	Manure	

Figure 10. Resource Trace

Start	C1	C2	C3	C4
Event07	Event22			
Event07	Event23			
Event07				
Event08				
Event08	Event22			
Event08	Event23			
Event09	Event33	Event16	Event42	Event18
Event09	Event33	Event16	Event41	Event18
Event09	Event33	Event16	Event43	Event19
Event09	Event35	Event17	Event45	Event21
Event09	Event35	Event17	Event44	
Event10	Event34			

Figure 11. Event Track

Since commitments mirror events, also commitment tracks and traces can be constructed. Two sequential commitments are identified by the fact that they relate to the same resource at the same location, controlled by the same organizational unit. The former commitment is recognized as a future resource increment (e.g., produce, take), the latter commitment is recognized as a future resource decrement (e.g., consume, give). Since every commitment is perceived as increment and decrement by the same organizational unit (for transformation and transportation commitments) or different organizational units (for transfer commitments), preceding and following commitments can

be identified and added to the commitment chain until it attains the desired length. Commitment traces identify the chain of commitments (i.e., transfer, transformation and transportations) that preceded a particular commitment, whereas commitment tracks identify the chain of commitments that followed a certain commitment.

A commitment trace allows supply chain partners to identify the critical path that precedes the fulfillment of commitments. When commitment tracks and traces are combined with the commitment summaries, which are constructed similarly to the event summaries (Figure 8), we can identify the economic resources and organizational units involved. For example, Butcher Pete's commitment to sell hamburger meat to Pizza Luigi can only be fulfilled when Butcher Pete's commitment to slaughter a cow and convert it into hamburger meat has been executed. However, that commitment can only be fulfilled on the condition that the commitment to transfer a cow from the cattle farmer to Butcher Pete has been fulfilled. When the committed cow is diagnosed with BSE, she will be removed from the food chain and the transfer commitment cannot be fulfilled. Consequently, Pizza Luigi will not be able to collect the committed lot of hamburger meat. To ensure Pizza Luigi's operations, alternative lots of hamburger meat will need to be identified. Such an alternative can be identified using the same traceability information. For example, by identifying a lot of hamburger meat that originates from another cow and has not been committed to any transfer yet. Consequently, a registration of future paths of products might be useful in mitigating the effect of supply chain intrusions. When a lot of products is destroyed or rejected, the effect on the remainder of the supply chain can be assessed and mitigating actions (e.g., delivery of alternative products) can be deployed in cooperation with the affected supply chain partners.

Similar to the event and commitment tracks and traces for product flows, presented above, event and commitment tracks and traces for money flows can be represented. With budgets as equivalents of lots, money can be partitioned to facilitate traceability and limit contamination (e.g., criminal money). Additionally, event tracks facilitate Paulian or revocatory action (OpenJurist, 1886), which enables creditors to reclaim their goods or money from a third party that is a trading partner of their debtor. The registration of money flows and the product flows they mirror may also provide tools to impede money laundering by enabling the tracing of the (criminal) activities in which the money originated. The registration of the future paths of products may indicate the intended use of products, which would ease signaling improper use of products at an early stage. Such product tracing infrastructure might also support product authentication (e.g., *appellation d'origine contrôlée*) in the battle on counterfeit and other supply chain intrusions (e.g., food safety scandals). Furthermore, commitment tracks and traces for money flows can facilitate estimating the effect of a bankruptcy (e.g., Who are the creditors and debtors and how severely will they be affected?).

Conclusions, and Directions for Future Research

This paper presented a conceptual model of inter- and intra-enterprise phenomena that can be used as a reference model for supporting applications of tracking and tracing for both enterprises and supply chains. This ability was illustrated with a prototype application for which we developed a data model and a database containing registrations that relate to both inter- and intra-enterprise phenomena. In particular, the example illustrates that the proposed model can be implemented such that it can be used to construct product tracks and traces from transaction data (i.e., transfers, transportations and transformations). Additionally, it illustrates that the registration of event and commitment perceptions enables us to trace and track the origin and (future) destination of product and money flows. The main contributions made by the model are the identification of the money flows that mirror the recorded product flows (Foster, 1922) and the identification of the future paths of products in a supply chain. These contributions advance the current interpretation of tracking and tracing, which is limited to recording the past path and present location/existence of products through supply chains and abstracts from the registration of money flows and future product flows (Bechini, et al., 2008).

The REA ontology, which is the theory behind our reference model, makes an explicit distinction between a trading-partner view and a so-called independent view on business assets and transactions. The former view specifies a business conceptualization from the sole perspective of one particular party involved in business, called the 'trading partner', which is for instance an enterprise doing business in its role of customer, producer or supplier. The latter view looks at business from an independent observer perspective or 'helicopter' view. It sees, for instance, business as flows of goods, services and money between parties that are caused by events initiated by these parties. It is clear that both views, respectively focused on intra-enterprise phenomena (i.e., transformations and transportations) and inter-enterprise phenomena (i.e., transfers), are integrated in our conceptual model as it is used to track and trace products through the production processes of multiple supply chain partners. From a theoretical perspective this integration of different perspectives is the greatest contribution of our reference model.

In the prototype application section, we showed how event and transaction summaries can be transformed in product tracks and traces (e.g., product history, product composition) as well as event tracks and traces (e.g., for monitoring a cold chain). In the future we would like to implement the proposed reference model for tracking and tracing to monitor real-world supply chains. With the

provided prototype we hope to have sufficiently illustrated the feasibility of such a real-world supply-chain monitoring system to motivate and fund the construction of a pilot application in a real-world supply chain.

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