Towards an Ontology of Traceable Impact Management in the Food Supply Chain

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Abstract

The need for quality improvement and accountability in food supply chains—particularly concerning outcomes like hunger—demands a comprehensive approach that integrates product quality with its impact on stakeholders and communities. A Traceable Impact Management Model (TIMM) provides a structured framework for evaluating stakeholder roles across production and consumption, enhancing traceability's role in assessing community-level impacts. Aligned with regulatory demands and stakeholder needs, TIMM is grounded in an ontological model that ensures consistent logic and terminology. This integrated solution fosters global traceability, promoting sustainability, accountability, and responsible food systems on a broader scale. With these combined efforts, the food supply chain moves toward a global tracking and tracing process that not only ensures product quality but also addresses its impact on a broader scale, fostering accountability, sustainability, and responsible food production and consumption.

Keywords

ontology engineering, quality measurement, food supply chain, traceability

1. Introduction

United Nations Sustainability Goal 2, "Zero Hunger," redirects attention from production metrics to the food supply chain's impact on stakeholders experiencing hunger and insecurity[1]. Achieving food security demands inclusive strategies—especially for vulnerable populations—emphasizing traceability of how supply chain activities influence access to safe, nutritious, and high-quality food.

Traceable impact in the agricultural food chain involves modeling production, processing, distribution, and consumption to assess socio-economic and environmental outcomes [1]. This requires robust data collection, impact analysis, and software tools to optimize outcomes and mitigate risks. A global framework is essential for tracking effects and supporting sustainable practices.

This paper introduces an ontology-based framework integrating impact management and traceability, grounded in ISO/IEC 5087-1 and the Common Impact Data Standard (CIDS). It presents the Traceable Impact Management ontology as a foundation for modeling, assessing, and improving stakeholder outcomes in the food supply chain.

1.1. Traceability in the Supply Chain

Traceability in the food supply chain entails tracking and retracing each step of food production, processing, transportation, and consumption, including who performed activities, when and where they occurred, and the quantity and quality involved [2, 3]. It supports food security's four pillars—availability,

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[1] https://www.un.org/sustainabledevelopment/hunger/

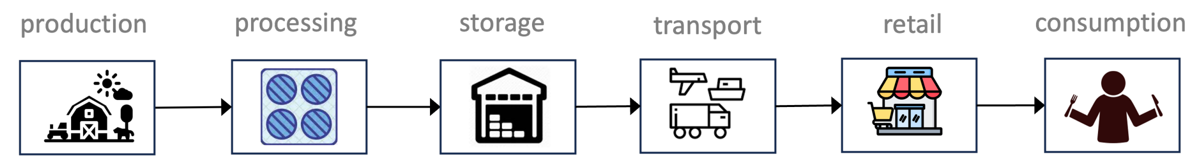

Figure 1: Beef food supply chain use case.

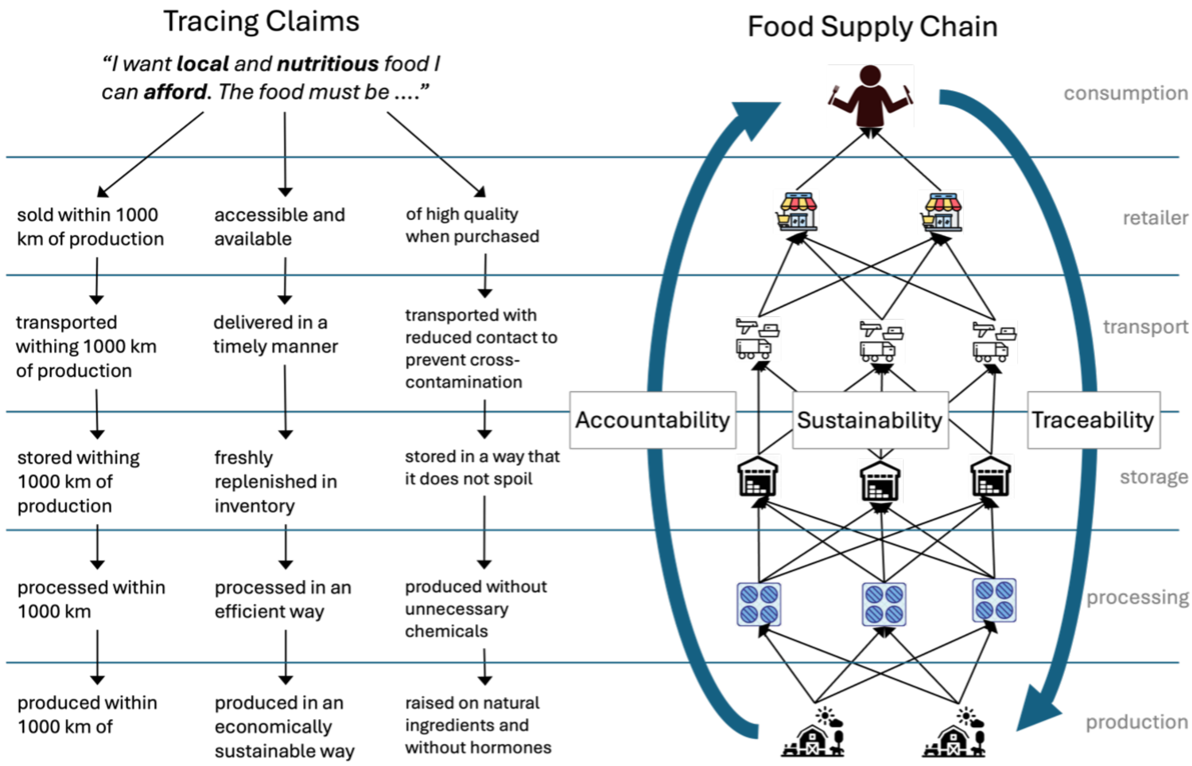

Figure 2: Beef food supply chain with claims, accountability, sustainability, and traceability.

access, utilization, and stability—by revealing the complexities in achieving sustainability, accountability, and traceability (Figure 1) [3, 4].

Beef production is impacted by environmental, biological, and socio-economic factors, including disease, worker conditions, and logistics. Cross-jurisdictional transport introduces risks of spoilage, contamination, and regulatory incompatibility, with economic variables like pricing and distance influencing access [5, 6]. Final delivery often reveals cumulative food insecurity risks such as expired or nutritionally compromised products.

Traceability fosters accountability from raw material sourcing to consumption (Figure 2). It enhances quality control, enables efficient recalls, supports regulatory compliance, and eliminates redundant inspections by sharing accurate upstream data. The food supply chain includes agriculture, agro-industries, trade/distribution, and supporting industries. Stakeholders span producers, processors, logistics, consolidators, and consumers.

Modeling traceability involves methodologies like Petri-nets, IDEF, EPC, UML, BPM, SADT, EDOC, and ADF [7, 8, 9, 10, 11, 12, 13]. These visualize and analyze workflows to improve traceability and operational efficiency. Effective modeling distinguishes planned networks from actual events, requiring data on actors, products, equipment, and transitions, captured using RFID, NFC, GS1, and EPC standards.

Traceability exists at two levels: internal (within organizations) and global (across systems). Internal traceability tracks detailed product data, inputs, equipment, and storage. Global traceability connects stages across stakeholders, focusing on broader data like origin, transport, and animal identification.

Both levels are essential for securing transparent, accountable, and sustainable food systems.

2. Traceable Impact Management

Impact encompasses the intended and unintended changes that affect organizations and their stakeholders over time as a result of activities[2]. In the food sector, such changes include outcomes influenced by production, labeling, and claims governed by relevant policies[3]. Despite varying frameworks like Logic Models or Theory of Change, impact models share core elements that enable unified representation [14]. The Impact Management Project[4] defines impact across six dimensions: What, Who, How Much, Contribution, Risk, and How. CIDS incorporates these to assess outcome nature, affected stakeholders, extent of change, and associated risks [15].

Within the food supply chain, impact management links outcomes to traceable events and resources, from sourcing to consumption. This approach accounts for food waste, safety, and sustainability as essential outputs of supply chain activities [16]. Traceability enhances stakeholder understanding of how supply changes can drive community benefits, such as improved environmental practices or food security. Visibility into raw materials motivates producers to maintain quality, boosting trust and accountability.

Further, traceable impact systems support timely interventions, like targeted recalls, when product issues affect downstream stakeholders. Identifying affected communities—especially distant or indirect ones—enhances response effectiveness and minimizes harm. These systems also improve quality control by linking material origins to community impacts.

Strategically, implementing traceability and impact management ensures regulatory compliance and market adaptability. It supports sustainability mandates, enables differentiation through transparent practices, and strengthens consumer confidence. As policy and consumer expectations evolve, these systems become vital for ethical, competitive, and resilient food supply chains.

3. Ontologies for Tracing Impact in the Supply Chain

This section reviews ontologies that underpin the Traceable Impact Management ontology: ISO/IEC 5087 and TOVE for representing enterprise activity and traceability; and CIDS for impact modeling.

3.1. TOVE and 5087

The ISO/IEC 5087-1:2023 standard, rooted in TOVE [17, 18], defines core concepts like activities, resources, time, agents, and organizational structures. Its Activities-State model identifies how actions emerge from enabling states and produce caused states. The TOVE-based activity abstraction further structures activities into sub- and super-activities, capturing their logical and temporal dependencies through clustered states, enabling a systematic trace of processes such as "produce ground beef."

Temporal modelling in 5087-1, based on OWL-Time [19, 20, 21], provides constructs for representing time-points, intervals, and temporal relations. These enable detailed scheduling and sequencing of activities and states, allowing planners to evaluate overlaps and precedence relationships for optimized coordination.

The 5087-1 resource ontology defines resources through quantity, unit, time, location, and allocation. It assesses divisibility and utility, supporting decisions on scheduling and impact tracing [22]. For example, splitting a batch of ground beef into multiple units contrasts with the indivisibility of a single patty box. Beyond raw materials, the ontology encompasses machines, energy, and labor, highlighting their social, environmental, and economic impacts throughout the supply chain—from production to transportation and consumption.

[2]https://innoweave.ca/en/modules/impact-measurement
[3]https://inspection.canada.ca/en/food-labels/labelling/industry/method-production-claims
[4]https://www.theimpactprogramme.org.uk/portfolio/impact-management-project/

TOVE's Traceability Ontology [23] formalizes quality through logical constructs, emphasizing conformance to requirements via sub-domains like measurement and traceability. The Traceable Resource Unit (TRU) defines resources at a specific time and place, quantifying them at the point of interaction with primitive activities. TRUs maintain fixed quantities post-creation and cannot be subdivided internally. Aggregation of multiple TRUs forfeits individual identity, necessitating careful handling for trace accuracy. Trace paths [24] connect TRUs and activities via *:PrimitiveTrace* instances, enabling a networked trace across the supply chain that supports granular quality and impact analysis.

3.2. Common Impact Data Standard

The Common Impact Data Standard (CIDS) [15], developed under the Common Approach to Impact Measurement[5], provides a standardized yet flexible framework for modeling and evaluating the impact of organizational activities. Initially aimed at social purpose organizations (SPOs), it addresses the challenges of consistent measurement and reporting across varying domains. Supported by multiple community partners and government funding, CIDS enhances the harmonization of impact measurement.

Standardization through CIDS enables unified data collection, supporting optimized impact delivery, complex analyses (e.g., longitudinal studies), and adaptable reporting for different stakeholders. It reduces administrative overhead by offering formats that meet diverse funder's requirements, enhances content discoverability online, and promotes integration with global standards like the UN SDGs, IRIS+, and IATI.

CIDS models impact using core classes: Organization (entity responsible for impact), Stakeholders (individuals or groups affected), Characteristic (codes identifying stakeholders), Activity (actions producing or enabling outcomes), Output (quantified activity results), Outcome (stakeholder experiences), Indicators (metrics with time, location, value, and units), Indicator Report (metric value over time), Impact Report (captures scale, depth, duration of outcomes), and Impact Risk (likelihood and materiality of deviation in impact). It integrates ISO/IEC 5087-1 ontologies for activities, resources, and time, enabling traceable and standardized impact representation across systems.

4. Traceable Resource Claim Patterns

This section defines the extensions to existing ontologies that focus on traceability of resources across changing states, claims made, and related stakeholders.

4.1. Resource Pattern

The *:Resource* pattern defines the relationship between the resource being discussed and the activity that changed its state and a stakeholder related to that activity, as demonstrated in Figure 3. The *:Resource* is a subset of Manifestation, extending it with three properties, :hasQuantity with amount and units of measure, :existsAt with its temporal dimension, and :hasLocation with its geospatial dimension. The resource is related to a *:TerminalState* as part of activities that change its state, which can be one of *:ProduceState*, *:ConsumeState*, *:ReleaseState*, or *:UseState*. For example the initial production of, say "beef" would be defined as a ProduceState, while consumption of that "beef" by the customer would be defined as a *:ConsumeState*.

4.2. Trace and PrimitiveTrace Patterns

To ensure resources are traceable, they are tracked using the *:PrimitiveTrace* class. Each *:PrimitiveTrace* class relates the resource at one point in time to another point with :traceFrom and :traceTo properties. Each *:PrimitiveTrace* is part of a continuous *:Trace* comprised of one or more individual *:PrimitiveTrace*

[5]https://www.commonapproach.org/

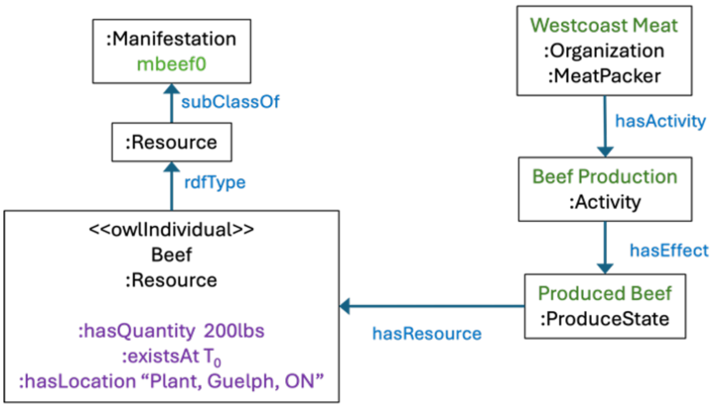

Figure 3: :Resource and TerminalState Design Patterns.

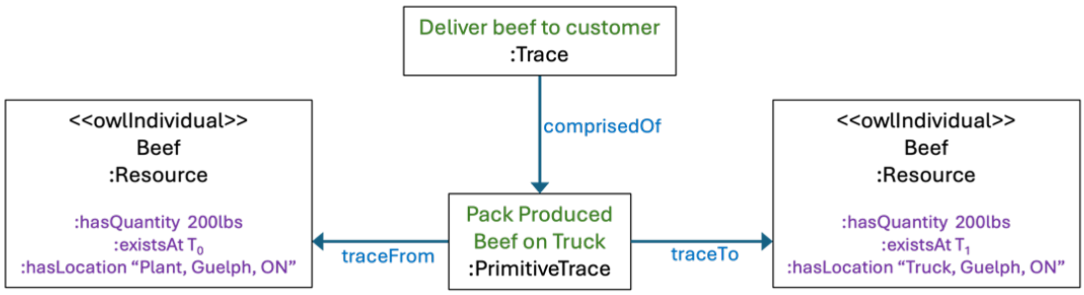

Figure 4: *:Trace* and *:PrimitiveTrace* Pattern for tracing a *:Resource*

instances, as demonstrated in Figure 4. It should be noted that :traceTo and :traceFrom properties for a :Resource are separate from :inputOf and :hasOutput properties that may be found in process ontologies. Rather, :traceTo and :traceFrom relate the :Resource to the :trace, not the activities that may have produced or used it.

4.3. Claim and Policy Patterns

The *:Claim* class identifies what claims are being made on a resource, such as "locally produced" and "organic." The *:Policy* class represents how those claims are defined. For example, given the *:Claim* of "locally produced," a *:Policy* can be defined that applies to the claim if and only if geospatial distance between the locations where the resource was produced (meat packer) and consumed (customer) is less than some predefined threshold, say 1,000km. Depending on the policy, different Resource properties can be referenced using the :satisfiedBy property. For example, in Figure 5 we see that the distance calculation relies on the two *:Resource* manifestations at times T_0 and T_1. The *:Policy* axiom can then be defined to reference properties as needed, namely the location of the resource. The trace pattern allows for the traceability of claims as the state of the resource changes, as demonstrated in Figure 5 . The *:Claim* is related to the *:PrimitiveTrace* the claim is for with the :claimFor property.

4.4. Indicator Pattern

In order to align the claims with outcomes that stakeholders are interested in, such as "eating locally produced food," the *:Claim* class is related to the CIDS *:Indicator* class. An *:Indicator* is used to report on whether the claim is true or not, given the state of the resource. The *:Indicator* reports on the boolean values of "true" or "false" indicating whether the claim applies or not, respectively, as illustrated in Figure 6. As long as the Policy applies to the claim, the *:Indicator*'s value can be reported as True.

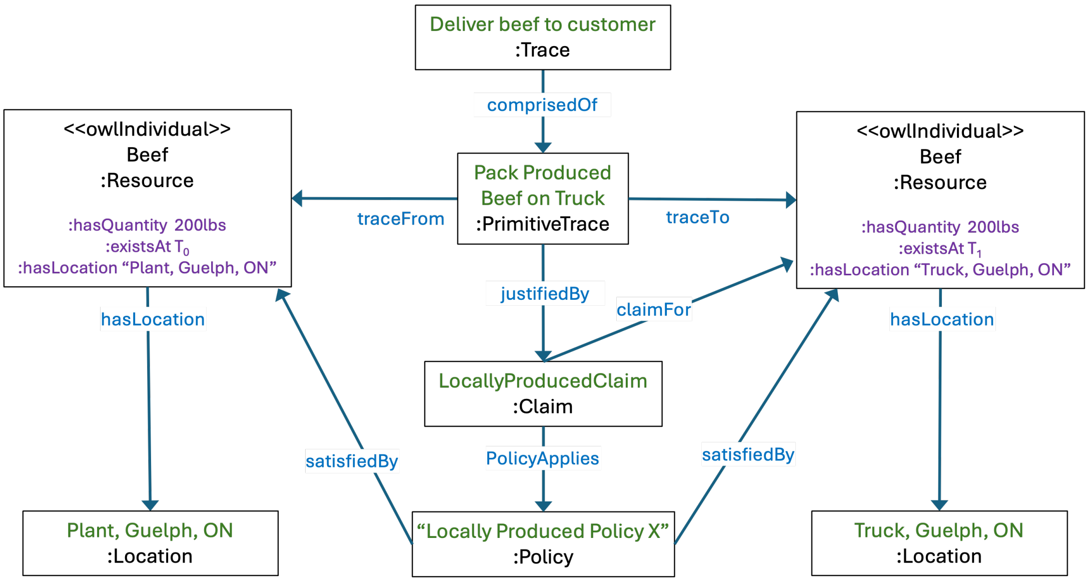

Figure 5: Policy example based on *:Location* of a *:Resource*.

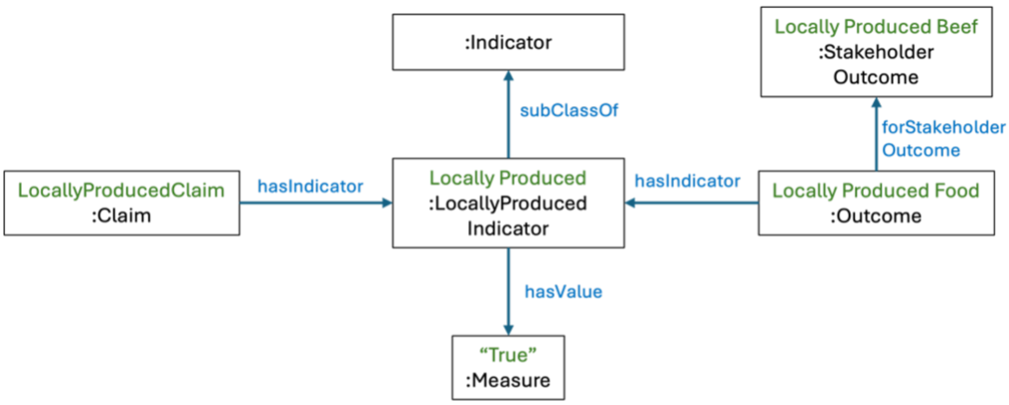

Figure 6: Indicator Pattern for Claims on a resource.

5. Integrating Impact Modeling and Traceability

We align the 5087-1 Activity and Resource ontology with TOVE's traceability ontology and CIDS indicators to construct a model for tracing impact. While CIDS provides a comprehensive model for representing activities and impact, TRUs provide a model to connect activities and resources at time points and locations. The proposed model simplifies the representation by: 1) replacing a *:TRU* with a *5087-1:Resource*, 2) replacing the "curp_tru" classes with corresponding *5087-1:TerminalState* subclasses, such as "produce_tru" with *:ProduceState*, and so on, 3) associate the *:PrimitiveTrace* class with the *:Resource* directly instead of the *:TRU*, and 4) assign the *cids:Indicator* with the *:Claim* class.

This allows us to assign *:TRU* properties that may change over time, namely quantity, time, and location to the *:Resource* class directly. Figure 7 illustrates a complete traceable resource and claim. Due to limitations of description logic-based ontologies, first-order-logic axioms are used to specify the semantics of the concepts. For example, the applicability of policy on a claim, such as Equation 1, requires rules that are not supported by description logic.

We demonstrate the model's usage in the next section with a scenario outlined from Figure 8 to Figure 12. Here, we are interested in the claim that food delivered to consumers is produced locally, where the definition of locally produced goods is anything that was produced within 1000km from the place of use or consumption. At each stage, the outcome stakeholders are interested in reporting on is

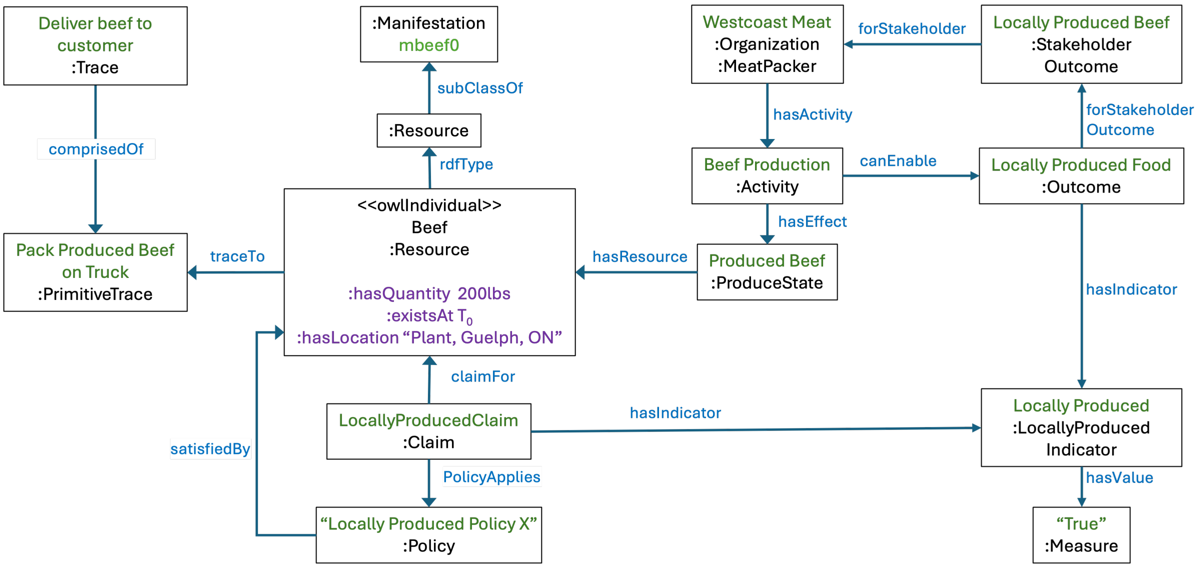

Figure 7: Example of a *:Resource*, *:Claim* about local production, policies which defined how this claim is determined, the stakeholder interested in the claim as their *:Outcome*, and the *:Indicator* capturing it for reporting purposes.

whether food product is locally produced.

To determine whether a *:Resource*, say "Beef," was used or consumed within 1,000 km of production, we rely on at least one *:Policy* that defines what "locally produced" means, at least one *:Claim* on that *:Resource* in question, an *:Indicator* that can be reported, and the *:Outcome* the stakeholder is interested in, as per Figure 7. As long as the *:Policy* applies to the *:Claim*, the *:Indicator*'s value can be reported as True. The *:Resource* "Beef" has a manifestation :mbeef0, to represent the existence of "beef" at time 0. It is linked to the *:PrimitiveTrace* which connects it to the next step in the trace, namely "Pack Produced Beef." This *:PrimitiveTrace* is part of the larger *:Trace* instance that will be extended in the next section.

Equation 1 provides an example of a *:Policy* axiom, which validates that the geospatial distance between a resource's first manifestation and its current position is less than or equal to some threshold value, say 1000km.

$$
\begin{aligned}
&\forall R_C,\ \exists P,\ \exists Q_T[\\
&\quad hasThreshold(P, Q_T) \\
&\quad \exists R_0,\ \exists Q_0,\ \exists L_0,\ \exists Q_C,\ \exists L_C\{ \\
&\qquad hasFirstManifestation(R_C, R_0) \wedge \\
&\qquad hasLocation(R_0, L_0) \wedge geo{:}asWKT(L_0, P_0) \wedge as\_nDLatLon(P_0, Q_0) \wedge \\
&\qquad hasLocation(R_C, L_C) \wedge geo{:}asWKT(L_C, P_C) \wedge as\_nDLatLon(P_C, Q_C) \wedge \\
&\qquad i72{:}Quantity(Q_T) \wedge i72{:}Quantity(Q_0) \wedge i72{:}Quantity(Q_C) \wedge \\
&\qquad ((Q_C \geq Q_0) \wedge (Q_C - Q_0 \leq Q_T)) \\
&\quad \} \supset LocallyProducedPolicyApplies(P, R, Q_T) \\
&]
\end{aligned} \tag{1}
$$

where

- R_C: Resource being evaluated at the current space and time
- L_0, L_C: Locations of resource R_C at the point of its first manifestation and its current (C) location
- Q_0, Q_C: Quantities representing the distance between the location where the resource R_C was produced and its current location

- Q_T: Quantity representing the threshold below which a resource is considered locally produced.
- P: Policy that defines what constitutes a locally produced resource.

The calculation is based on the latitude and longitude of the locations being compared, namely the location of the first manifestation at L0 and the current location at LC.

In Equation 2, we give an example of a *:Claim* axiom for the LocallyProducedClaim. This axiom defines what resource R and policy P the claim C is for.

$$
\begin{aligned}
&\forall C,\ \exists R,\ \exists P[LocalyProducedClaim(C,R,P) \equiv \\
&\quad \exists S\{ \\
&\quad\quad Claim(C) \wedge Policy(P) \wedge Resource(R) \wedge \\
&\quad\quad TermnialState(S) \wedge hasResource(S,R) \wedge \\
&\quad\quad LocalyProducedPolicyApplies(P,R) \wedge claimFor(C,S) \\
&\quad \} \\
&]
\end{aligned} \tag{2}
$$

where

- C: Claim representing the impact claim
- R: Resource the impact claim is made about
- S: A terminal state for resource R
- P: Policy that defines what constitutes an organic resource

Finally, in Equation 3, we give an example of an *:Indicator* and its claim, namely the *:LocallyProducedIndicator* I, its corresponding truth value M, and its claim C.

$$
\begin{aligned}
&\forall I\ \exists M[LocallyProducedIndicator(I) \rightarrow \{ \\
&\quad \exists C\ \ \exists R\ \ \exists P\{ \\
&\quad\quad LocallyProducedClaim(C,R,P) \wedge Resource(R) \\
&\quad \} \equiv \big(hasValue(I,M) \wedge value(M,''true'')\big)\} \wedge \{ \\
&\quad \neg\exists C\ \ \exists R\ \exists P\ \{ \\
&\quad\quad LocallyProducedClaim(C,R,P) \wedge Resource(R) \\
&\quad \} \equiv \big(hasValue(I,M) \wedge value(M,''false'')\big)\} \\
&]
\end{aligned} \tag{3}
$$

- R: Resource being evaluated at the current space and time
- C: Claim being evaluated
- P: Policy that defines what constitutes a locally produced resource.
- I: Indicator used to measure whether a claim is true or not
- M: Measure used to store the value of indicator I, where the value type is a boolean

5.1. Motivating Scenario: Locally Produced Beef

In the following scenario, a meat packing plant in Guelph, ON produces 200 lbs of beef, which is transported 664 km to a grocery store in Montreal, QC where it is purchased by consumers. As shown in Figure 8, the organization "Westcoast Meat" is an instance of class *:MeatPacker*, and the CIDS class *:Organization*. It performs the activity of producing beef ("Beef Production"), which is an instance of the *5087-1:Activity* class. At time T_0 the organization performs the "Beef Production" activity which produces 200 lbs of beef at their plant in "Guelph, ON." The activity has the effect of creating the

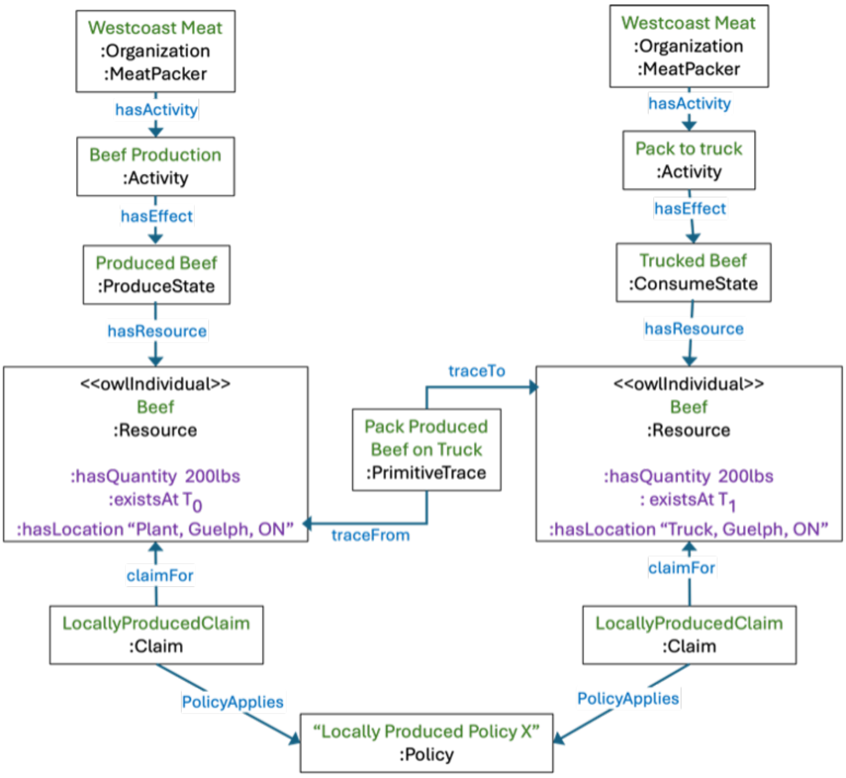

Figure 8: Tracing a *:Resource* example: after the production of beef patties, they are packed onto a truck.

:ProduceState at the time point T_0, signifying the creation of 200 lbs of beef at location "Plant, Guelph, ON." At this point, the "beef" becomes an instance of a *:Manifestation*, superclass of *:Resource*. While trivially true, illustrates the representation of the "LocallyProduced" *:Claim* for this Resource. The *:Resource* has the location "Plant, Guelph, ON" as the location of production.

Figure 8 also illustrates the next activity and changes in the *:Resource*, namely the packing of produced beef onto a truck. The packing of the beef onto the truck, "Pack Beef", is an instance of the *:ConsumeState* class since it consumes the existing resource, 200 lbs of beef, at time point T_1. The location has changed from "Plant, Guelph ON" to "Truck, Guelph, ON." This example illustrates the linking of two *:Resources* using the *:PrimitiveTrace* class, which links a *:Resource* to another. In Figure 8, the "Pack Produced Beef on Truck" *:PrimitiveTrace* is a trace from "Beef Production" *:Activity* to the next activity, "Pack to Truck."

According to the LocallyProducedPolicyApplies axioms in Equation 1, the locations of activities "Produced Beef" and "Pack Beef" are used to calculate the difference, with a *:Measure* value of "0.1 km". Given that the beef was packed onto a truck 0.1 km away, it also satisfies the claim that the beef is locally produced, and the "LocallyProduced" Indicator has a value of "True."

Figure 9 illustrates the next activity's *:Resource*, namely the transport of the produced beef. The organization "Bob's Trucking" is an instance of both the *:Trucker* class and *:Organization* class. It transports beef from "Truck, Guelph, Ontario" to its final destination, namely "Truck, Montreal, Quebec." The "Trucked Beef" *:UseState* transition's the beef's state from "Produced Beef" to "Trucked Beef" since it uses the resource beef without consuming any of it, creating a new *:Resource* at time-point T_2. Given that the transport's destination is within 1000 km, it also satisfies the claim that the beef is locally produced, and the "LocallyProducedClaim" has a value of "True."

Figure 10 illustrates the next two steps in the supply chain, namely the unloading and stocking the beef to the grocery store 644 km from the meat packer. At time point T_3, the grocery store organization "Joe's Supermarket" receives the beef and unloads it in their store. "Joe's Supermarket" is an instance of both the *:GroceyStore* class and *:Organization* class. It performs the "Unload Beef" activity which "releases" it from the trucks possession of the beef. Next, it performs the activity of "Stock Beef", creating

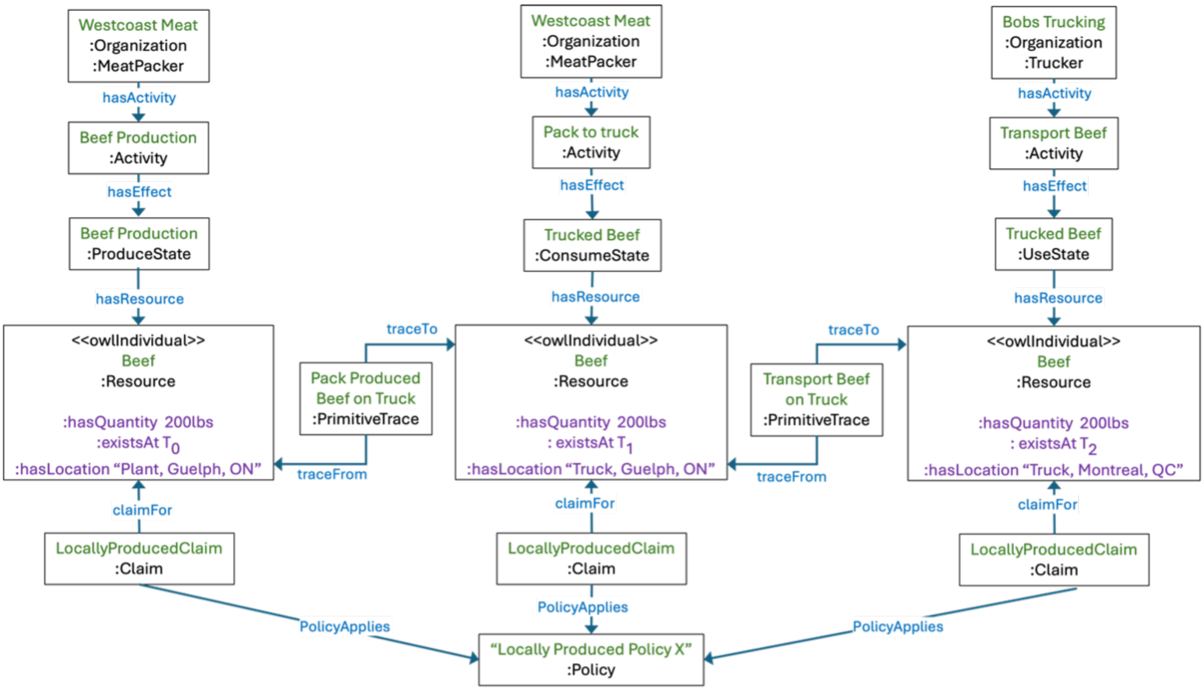

Figure 9: Tracing a *:Resource* claim example: after production of beef patties and packing them on a truck, they are transported by a trucking organization.

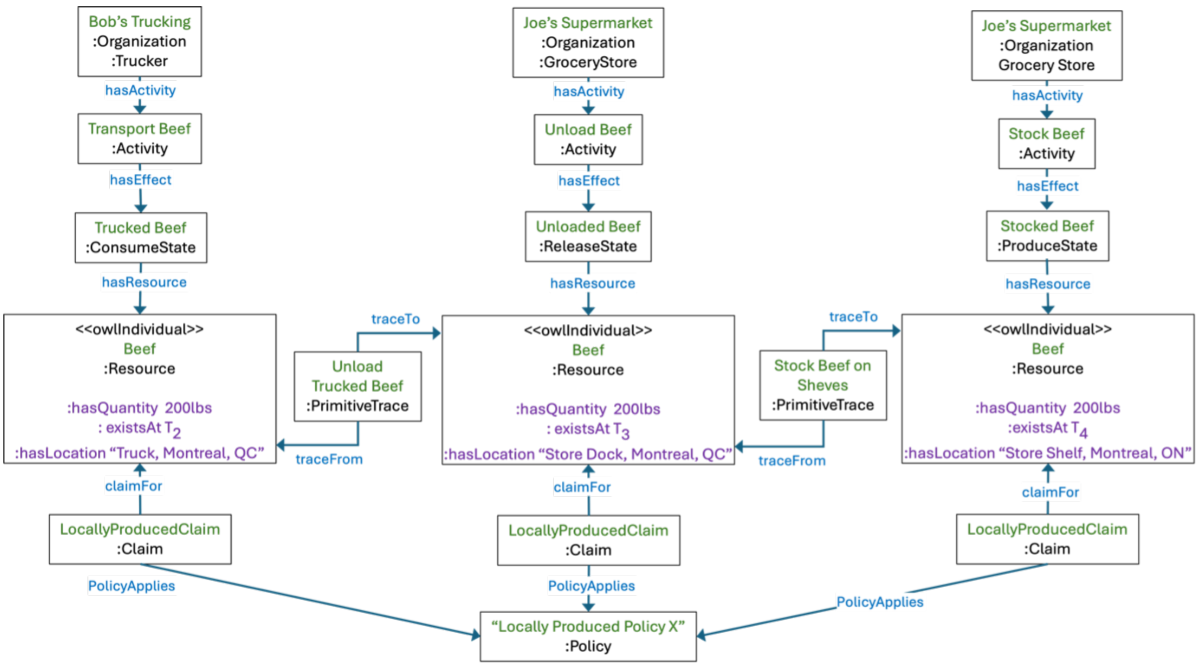

Figure 10: Example: Tracing a claim for producing beef patties and transporting them to Montreal.

the *:ProduceState* at T_4 with 200 lbs of beef. Again, since the location of the "Stocked Beef" *:Activity* is within 1000 km of the meat packer, this beef is locally produced, and the "LocallyProducedClaim" is "True" at time-point T_4.

5.2. Policy and Claims across a Trace

The final step in the supply chain is the selling of beef to consumers. Figure 11 illustrates this by tracing the buying of 2 lbs of beef by a consumer at time point T_5. The consumer "Mary", is an instance

Figure 11: Example: Traceable claim for locally produced beef purchased by a consumer after beef was stocked.

of the *:Consumer* class as well as a member of the CIDS class *:Stakeholder* that identifies a group of stakeholders that are interested in buying locally produced food. The consumer performs the activity of "Buy Beef" in the amount of 2 lbs at time-point T_5. This activity transitions a portion of the 200 lbs of beef, namely 2 lbs, from "Stocked Beef" to "Bought Beef," creating a *:ConsumeState* :tru at time point T_5 for 2 lbs of the beef shipment.

In Figure 8, the "Locally Produced Policy X" is calculated according to Equation 1 from the point of production to point of consumption by the customer. The locations of "Produced Beef" *:Resource* ("Plant, Guelph, ON") and "Bought Beef" *:Resource* ("Home, Montreal, QC") are used to calculate the difference indicator with a value of "644 km". Given that the beef was bought 644 km away from being produced, it satisfies the claim that the beef is locally produced, and the "LocallyProduced" indicator has a value of "True" at T_5. Hence, the "LocallyProducedClaim" is true. By tracing the claims across all primitive traces that comprise the main "Deliver beef to customer" *:Trace*, the claims remain true throughout.

Finally, in Figure 13, we align the newly calculated "LocallyProduced" indicator with the outcome consumer "Mary" is interested in. The consumer's *:Activity* instance "Buy Beef" has an effect, namely the *:ConsumeState* of "Bought Beef." An instance of the *:StakeholderOutcome* class represents the outcome the consumer is interested in, namely "Buy Local Food." The indicator "LocallyProduced" is then linked to the stakeholder outcome through the hasIndicator property. The LocallyProducedPolicyApplies axiom ensures that the claim and Indicator are true. Again, the "Locally Produced" calculation is based on the calculated distance "644 km" and threshold of "1000 km", giving "True" for the "LocallyProduced" indicator value.

6. Discussion

The proposed model outlines an ontological framework for the representation and mechanics of how to integrate impact modeling, activity modeling, and traceability. The model focuses on the transformation of resources as they move through a supply chain. The resources are tracked through four different types of changes imposed by an activity, namely production, use, consumption, and release. The claim class allows one to place a label on the state of the resource, while a policy allows one to define how the claim is determined. Separating claims and policies in this way allows us to define one label for multiple

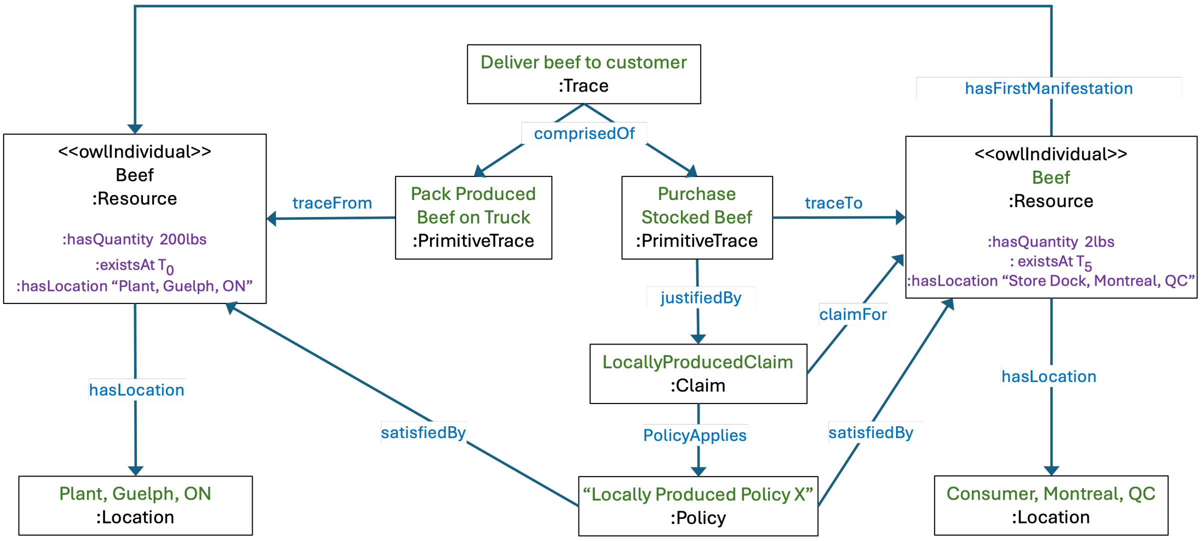

Figure 12: Example: Traceable claim for locally produced beef for the consumer traced back to the point of production at the plant.

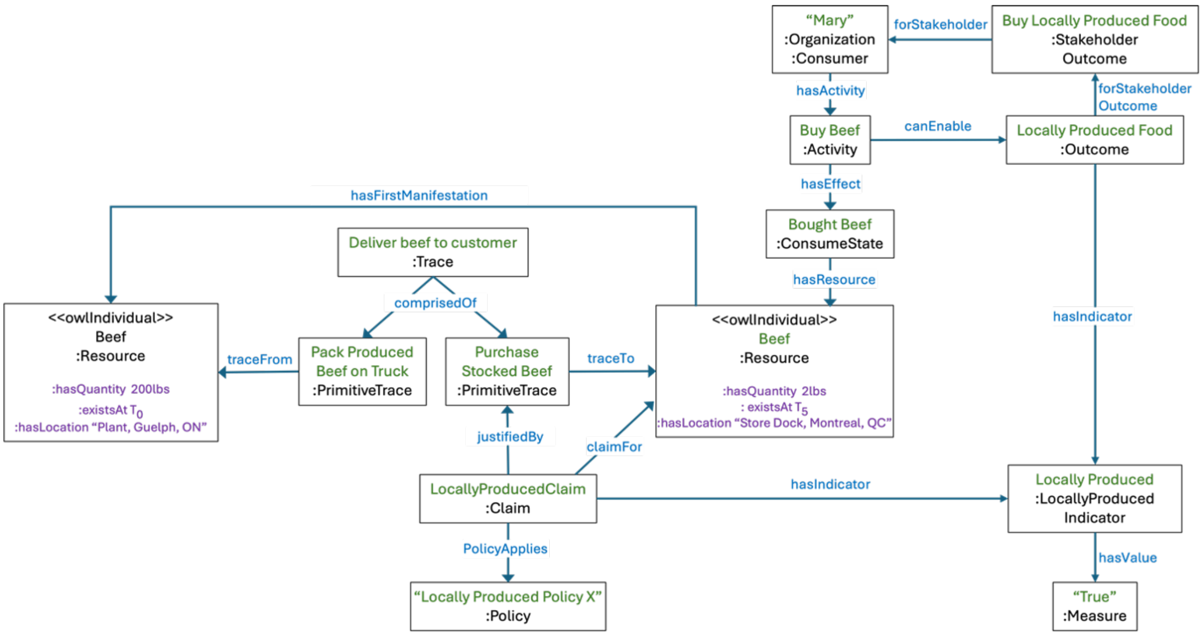

Figure 13: Indicator for locally produced beef at point of sale to consumer.

policies, ensuring that a claim can be defined in more than one way. By representing the changing state of the resource as part of a trace, we can track what activities occurred during various stages of the resource, moving backwards and forward in time, evaluating the claim's applicability at each point. Finally, by extending the claim pattern with CIDS, we can associate each claim with a stakeholder and a desired outcome, relying on the impact indicator to report on whether the claim is true at any given point in time during the trace.

The provided scenario illustrates the model's ability to trace the claim of "local production" as it pertains to the production, transport, sale, and consumption of beef. The model could be extended beyond sales and identify other impacts on the consumer and beyond, such as the environment. For example, the model can trace how a consumer's nutrition levels are impacted. With the use of counterfactuals, we can identify the risk of, say, not delivering beef to grocery stores on the consumer's nutritional intake of protein and other nutrients. In our scenario, 200 lbs of beef would impact 100 consumers in the community. This shortfall must be reconciled by other means. Not doing so would pose a risk to the healthcare system by potentially causing malnutrition in parts of the population.

Equally, we can trace the environmental risk of food supply chain. For example, consider that the beef is not transported properly above, say 4.4C, and must be thrown out. While the consumer is impacted by not consuming the beef, the environment is impacted by producing food waste, adding 60,000 kg of carbon dioxide and contributing to global warming. Meanwhile, the rotten beef and packs need to be dealt with separately due to different material properties. Rotten beef will be incinerated and continue to produce greenhouse gases, while the pack of plastic may go to a landfill, especially in some developing countries, thus creating further damage to the soil structure.

7. Conclusion

This paper presents the Traceable Impact Management Model (TIMM), an ontology-based framework for aligning food supply chain traceability with societal and environmental impact claims. Built upon ISO/IEC 21972, 5087-1, and the Common Impact Data Standard, TIMM enables a comprehensive connection between product quality and broader stakeholder outcomes, addressing hunger and sustainability while meeting evolving regulatory and consumer demands.

At its core, the model defines a unified terminology to represent stakeholders, resources, and their transformation across production, use, consumption, and release. A claim-policy structure allows for evaluating the state and trajectory of resources, while impact indicators provide validation of stakeholder outcomes [15]. By tracing resource history and associating claims with specific actors and objectives, the model supports proactive assessments and actionable recommendations to improve systemic accountability across the supply chain.

TIMM offers a coherent logic for modeling data artifacts and quality processes, enabling stakeholders to visualize goods' transformations. Its shared vocabulary ensures consistent understanding and coordination. Additionally, this ontological framework provides the foundation for developing software systems that capture and analyze data for traceability, supporting quality assurance, recalls, and regulatory compliance. Through this integration, TIMM fosters a globally traceable, accountable, and sustainable food system.

Declaration on Generative AI

The author(s) used Grammarly to spell-check and ChatGPT-4o to reduce length of some paragraphs in this work. Authors reviewed and edited the final publication, and take full responsibility for its content.

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