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DOI
10.3233/ATDE200061

Publication date
2020

Document Version
Final published version

Published in
Transdisciplinary Engineering for Complex Socio-Technical Systems - Real-Life Applications - Proceedings of the 27th ISTE International Conference on Transdisciplinary Engineering

Citation (APA)
Wever, M., Wognum, N., Shah, M., Sharifi, M., & Reis, M. M. (2020). Transdisciplinary approach to hyper-transparency. In J. Pokojski, M. Gil, L. Newnes, J. Stjepandic, & N. Wognum (Eds.), *Transdisciplinary Engineering for Complex Socio-Technical Systems - Real-Life Applications - Proceedings of the 27th ISTE International Conference on Transdisciplinary Engineering* (Vol. 12, pp. 60-69). (Advances in Transdisciplinary Engineering; Vol. 12). IOS Press. https://doi.org/10.3233/ATDE200061

J. Pokojski et al. (Eds.)

doi:10.3233/ATDE200061

Transdisciplinary Approach to Hyper-Transparency

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Abstract. Over the last decade, transparency schemes have started to undergo a radical transformation. This transformation is driven by advancements in cloud computing, cryptography and automated measurement technology, which have made it possible to develop shared information management systems (SIMS). These SIMS form the backbone of the latest, state-of-the-art in the transparency space: hyper-transparency schemes. These new transparency schemes and associated SIMS offer companies, both small and large, the opportunity to redesign their supply chains and to establish more direct relationships with their second- and third-tier trading partners, as well as with the consumer. However, the companies also face various challenges in implementing and operating such hyper-transparency schemes. There are legitimate concerns about privacy, ownership and access to data and, related to this, who controls the SIMS. The present paper discusses the ongoing development of a SIMS. The objective of this SIMS is to: (1), help empower smallholders in agri-food supply chains to establish more direct connections with the consumer; and (2), help empower consumers to get more direct insight into the manner in which their food stuff is being produced. The paper presents the design of the SIMS and discusses its transdisciplinary development processes.

Keywords. Transdisciplinary, transparency, hyper-transparency, shared information management systems, supply chain redesign

Introduction

Over the last decade, transparency schemes have started to undergo a radical transformation. This transformation is driven by advancements in digital technologies, which have made it possible to develop shared information management systems (SIMS). The development of a SIMS is a challenging task. As with all new technology it is important not only to develop a robust system that is useful and usable, but also a system for which the impact on the user community and the society are well anticipated. In the literature, examples can be found of systems which had a large (often unanticipated or unexpected) impact on the procedures and working culture of a company or supply chain, (see e.g., [1]). Always, an information system alters the way people work, while, conversely, people also alter the way in which the system was supposed to be used.

The development of a SIMS requires collaboration between several different disciplines, preferably both from technical and social-science disciplines and from both practice and academia. Engineers alone are not sufficient. People with knowledge of the

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context in which the system needs to function, in this case supply chains with improved transparency and hyper-transparency (see section 1), as well as people from the social sciences who can apply methods to identify user interface needs. The development of such a system, therefore, requires a transdisciplinary approach (see e.g., [2, 3]). With such an approach the context of the system under development as well as of the business, in this case the supply chain, is well taken into account. The context can be wide, not only including the use context, but also the political, financial, cultural, etc., context.

In this paper an example of the development of a SIMS is presented. This SIMS is targeted at New Zealand agri-food supply chains and is intended to help companies create hyper-transparency schemes. Such schemes enable companies to give the consumers, as well as their supply chain partners, direct and real-time insight into the origin and production circumstances of the inputs or end-product that they are buying.

The goal of the system is twofold. Firstly, to help New Zealand companies restore consumer confidence at home, where farmers and food companies are under threat to lose their social license to produce because of environmental and animal welfare concerns. Giving consumers direct insight into the farm their products come from, and especially into the efforts the farmers undertake to take care of their animals and to limit environmental waste, could bring consumers and farmers closer together. Second, the objective is to help ensure the continued confidence of overseas consumers in the safety of New Zealand food products. Especially in a post-COVID-19 world, companies and supply chains that can demonstrate in real-time that they are going the “extra-mile” to ensure food safety, are likely to gain a significant premium.

The outline of the paper is as follows. In Section 1 we contrast traditional transparency schemes with hyper-transparency schemes. In Section 2 we describe how the SIMS functions. In section 3 we describe its development process. Section 4 concludes the paper.

1. From transparency to hyper-transparency

Up until the late 2000s, transparency schemes encouraged the consumer to rely on the monitoring activities of retailers and certifying institutions to guarantee a product’s origin and quality (e.g., [4, 5]). This required little involvement of the consumer, but also meant little real transparency: the consumer was asked to “trust” a label, stamped onto the product (see [6]). However, over the last couple of years, new transparency schemes have emerged to facilitate and encourage consumers to become more directly “involved” in the food production process. This has enabled consumers to actively monitor product attributes or production process characteristics by themselves.

Transparency schemes in the 2000s can best be characterized as link-to-link information systems, with an uni-directional focus, that were grounded in fragmented IT architectures (see Figure 1). Link-to-link in this context means that information almost exclusively flowed from one stage in the supply chain to the next, and rarely skipped a stage in the process (e. g., one-step forward or backward; see [7, 8]). Uni-directional means that the efforts at transparency were mainly oriented towards providing more information to downstream agents about the activities of the upstream agents, rather than also providing the upstream agents with information about downstream activities (see [9]). The IT architectures supporting the transparency schemes were fragmented, because most agents stored information in their own private databases (e.g., about production processes activities, product attributes, measurement results) that had limited or no direct connectivity to the databases used by agents elsewhere in the supply chain (an issue not just limited to the agri-food sector; see [10]). Combined with the link-to-link nature of the information flows, this meant that the information that was generated upstream in the supply chain was relatively slow to reach the downstream agents and not always reliable.

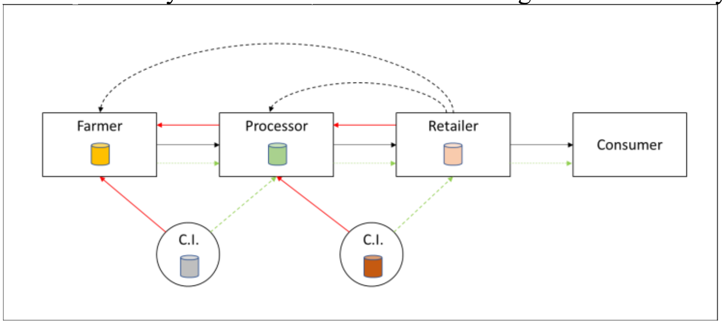

Figure 1. Typical transparency scheme (2000s).

Uninterrupted black lines: flow of products; interrupted black lines: flow of standards; uninterrupted red lines: monitoring activity; interrupted green lines: quality signalling; CI: certifying institution; different color-coded cylinders represent proprietary databases.

Advances in digital technologies over the last decade, especially in the area of cloud computing and cryptography, have started to transform the nature of transparency schemes. These advancements have made it possible to develop shared information management systems (SIMS), which form the backbone of these new transparency schemes (e.g., see [11]). We refer to these new types of transparency schemes here as “hyper-transparent”, to clearly differentiate them from older schemes (see Table 1).

These SIMSs function by ensuring that: (1), the individual databases of the parties participating in the transparency scheme run on the same IT architecture; (2), these databases are connected; (3), changes cannot be made to individual database as long as these changes are not approved by (some of) the other agents; (4), once changes are approved, they appear in other databases as well (e.g., [12, 13]). De facto, this means that each agent holds a copy of the same database, and therefore has – potentially at least – access to the same data. This makes almost real-time flows of validated data possible; data that can be bi-directional in nature and link-to-system rather than link-to-link.

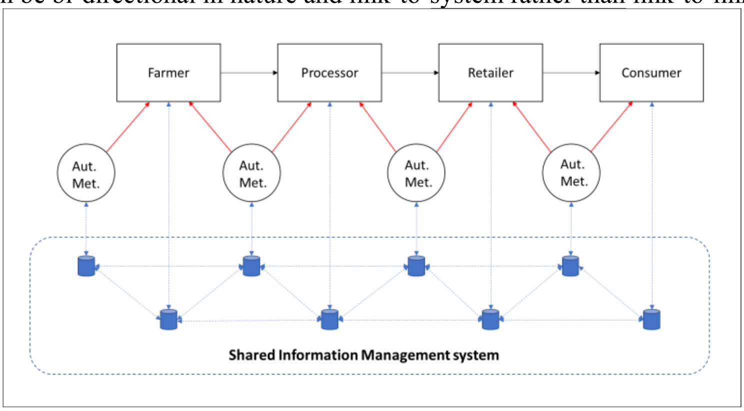

Figure 2. Example of hyper transparency scheme.

Uninterrupted black lines: product flows; uninterrupted red lines: monitoring activity; interrupted blue lines: information flows; the blue cylinders represent copies of the same, shared database; Auto Met.: Automated metering.

Arguably the most revolutionary aspect of these SIMSs is that they, together with improvements in measurement technology, can help to transform some credence attributes of food products into search attributes. Consumers could get, at least as long as the (major) parties participating in the transparency scheme agree to this, direct access and data points about what is happening at the processing or farm level. They would no longer be forced to delegate monitoring duties to other agents, but could, if they wish so, also do it themselves. Thus, for example, a consumer could potentially get direct insight into how animals are treated in different processing plants, when he/she is comparing meat products in the supermarket (e.g., via a live camera feed, accessed via an QR-code on the food packages). Animal welfare, in this scenario, would no longer be a credence attribute, but would become a search attribute (at least to a certain degree).

Furthermore, bidirectional flows of information, where the upstream agents get more insight into what happens downstream in the supply chain, could also change the way in which the companies in the supply chain deal with each other. Amongst others, they could help to reduce and mitigate some disputes in the supply chain. For example, if an upstream agent can track in real-time how long it takes for its outputs to move through the supply chain and see for itself immediately when there is a delay somewhere, it could make it more receptive to a delay in payment. Additionally, these bidirectional flows of information can also strongly enhance the ability of upstream agents to get direct and unmediated insight into consumer interests and behaviour. To return to the example given above, a processing plant could get insight into the frequency by which consumers scan the QR-code on the food packaging, etc.

Of course, hyper-transparency schemes have potential drawbacks as well. There are legitimate concerns about privacy, ownership and access to data and, related to this, who controls the SIMS. In many cases, the implementation of SIMSs is driven by the larger companies in the supply chain, such as retailers (e.g., [14, 15, 16]). These large companies de facto control who gains access to what part of the database. Therefore, while the other agents in the supply chain could easily have access to the same data as the retailer, usually they have access to only part of the database. In such cases, the potential of SIMSs for supporting bidirectional and "stage-skipping" information flows remain largely unfulfilled. Furthermore, the suppliers of SIMSs, who usually are large IT firms (see [17]), may become key "middlemen" in the agri-food industry [18]. These firms may make it difficult for the users of a SIMS to switch to another SIMS, thereby locking them into a relationship they cannot easily get out of.

Table 1. A comparison between transparency and hyper transparency schemes.

	Traditional Transparency Scheme	*Hyper-Transparency Scheme (ideal type)*
Focus of transparency efforts	Mainly **uni-directional;** providing downstream agents (e.g., retailers, consumers) more insight into the operations of upstream agents (e.g., farmers).	**Bi-directional**: providing downstream agents (e.g., consumers) with direct insight into the operations of upstream agents (e.g., farmers), and the latter also with direct insight into the needs and behaviour of the former.
Information flows	Mostly **node-to-node**; preceding, accompanying or following the flow of inputs/outputs throughout the supply chain.	**Node-to-system**: once a link in the supply chain releases information, it becomes available to all the other links at the same time.
IT architecture	**Fragmented architecture**, characterized by **isolated silos of data.**	**Integrated architecture**, underpinned by a **shared information management system.**

Speed and accuracy of information exchanges	Comparatively **slow**, **error-prone** information exchanges as a result of node-to-node communication that is “supported” by a fragment IT architecture.	Almost **instantaneous exchange** of **validated information**, that is much **less error prone** due to: an integrated IT architecture, multiple automated measurement technologies to triangulate the validity of measurements, use of sophisticated encryption technology.
Support of consumer monitoring efforts	The scheme encourages and asks consumers to **rely on the monitoring activities of third-parties** (e.g., certifying institutions, regulators) and food sellers.	The scheme facilitates and **encourages active and direct monitoring by consumers** of product attributes and production process characteristics.
Impact on consumer – seller/producer information asymmetries	The underlying **information asymmetries are not addressed**, but are shifted to the ‘relationship’ between the consumer and monitoring agencies. Consumers are asked to have confidence in the monitoring activities of these agencies.	By facilitating direct monitoring by the consumer, the scheme can **transform** (some) **credence attributes** (e.g., animal welfare) of food products **into search attributes** (e.g., by giving the consumers the opportunity to verify animal welfare by themselves).

2. The Envisioned system

The SIMS that we are developing is being designed specifically for smallholder-led supply chains. A SIMS can support smallholders by drastically lowering the time and costs of keeping track of the origin of food products along the supply chain. This could enable more smallholders to market their products as differentiated goods to consumers and it could also enable consumers to link the products they are buying to a specific farmer or farm-systems. With this in mind, the objective in designing the system was twofold: (a), to help farmers in establishing more direct relationships with their consumers; (b) to give consumers direct insight into how their food-products are made.

The system is made-up of five sub-components: (1), a farm- module; (2), a post-farm gate module; (3), a consumer module; (4), a communication module; and (5), an infrastructure module supporting the other four elements.

The farm-level module (see Figure 3) refers to the sub-system through which data is collected at the farm. Mostly, this will be done via sensors and IoT enabled devices, that automatically collect farm-level data (e.g., environmental data, data about animal behaviour, etc.) and uploading it to the cloud. For example, we are planning to use GNSS positioning sensors on cows, enabled with LoRA wireless technology, to track and record the activities of the animals and benchmark this data against indicators of animal health. We also intend to use WiFi-enabled cameras with motion detectors that can track the animals around the farm to provide a visual indication of how the animals are doing. Also, farmers will also be able to manually upload farm data to the cloud (e.g., information about their water usage).

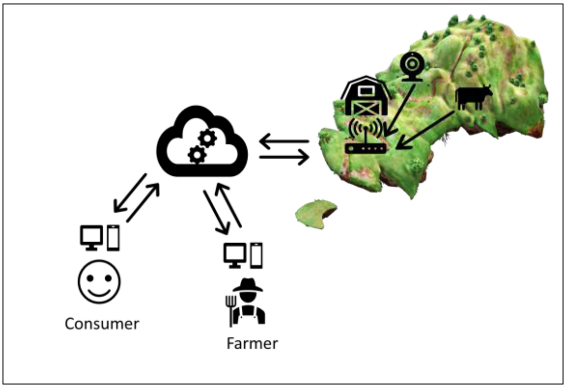

Figure 3. Overview of farm-level module.

In the post-farm gate module, we aim to deal with the problem of gathering and integrating verifiable information into the SIMS about agricultural “inputs” or “products” after they have left the farm gate. In many agri-food supply chains this can be challenging. For example, it is often difficult to keep track of products at the processing stage of the supply chain [19]. At this stage, “inputs” from different types of farm often get mixed and it can be prohibitively costly for the processor to keep product flows from different types of farm separated. Technological advances, however, give companies in the supply chain a couple of options around this problem. Firstly, technologies are being developed in some agricultural supply chains that allow farmers to undertake processing activities by themselves (e.g., such as on-farm dairy processing). Subsequently, the farmer can sell its products directly to the consumer. Secondly, novel measurement and sensor technology have been developed that when linked to a SIMS, help to drastically reduce the time and costs of: (a), keeping track of the origin of food products (e.g., DNA based-tracing of premium meat products); or (b), providing verifiable information about product attributes that can link measurements at the processing stage of the supply chain back to the type of farming system under which the products have been produced. Box 1 gives an example of the latter. This is a methodology that AgResearch is developing for the dairy industry, and our SIMS will be linked to it.

Milk composition and structure is significantly affected by the type of farming system under which the milk is produced (e.g., type of feed), by cow breed and by seasonal factors. AgResearch is investigating a cost-effective way to assess milk attributes based on these factors, both at the farm and at the processor. The ability to collect information about milk attributes throughout the supply chain will support a more transparent way to provide verifiable information to the consumer. In the method under development at AgResearch, ‘molecular signatures’ are traced that give an indication of the various earlier mentioned “value-added” attributes of milk. This molecular signature can be evaluated at the farm gate and the factory gate through the help of a special sensor. A mathematical model helps the company to relate the measurements taken to the value-added attributes of the milk.

Box 1: Verifiable milk attributes

Through the consumer module, buyers of food products can get insight into how their products are made. Here, the main concerns are: (1), how to make the process of getting access as easy as possible for consumers; (2), how can we stimulate them to actually engage with the platform. To deal with the first challenge, we will be using QR-codes, whereby consumers scan a code on the packaging of the food product with their phone and then visit the farmer's website (see Figure 4 for a prototype). To deal with the second challenge, we have analysed existing websites in the food-transparency space and are undertaking a consumer survey. Our preliminary analysis suggests that gains can be made in the following areas vis-à-vis existing approaches: "personalizing" information (e.g., by showing information about individual animals), using more audio-visual information (e.g., through live video-feeds of the farm), by presenting such information in an engaging fashion (e.g., we intend to track animals around the farm through cameras with motion-detection sensors), and by presenting "numerical" data in a "visual" manner.

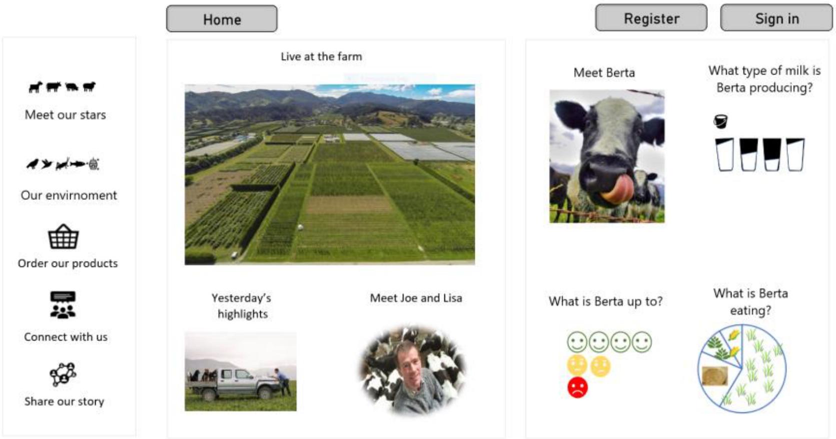

Figure 4. Overview of consumer module.

As shown in Figure 5, the infrastructure module is a cloud-based online platform. Data from the farms and other components of the supply chain are directly and continuously collected via IoT devices and transferred to the data warehouse or data lake managed in the shared system in the cloud. There are three components to this platform. First, the data management system is designed using the schematic proposed in Figure 2. Second, an automated data processing algorithm is implemented to check the quality of data and convert data into desired formats. Data governance, security protocols and proper access control for all actors in the supply chain are implemented here. Third, a data visualization and reporting system is under development.

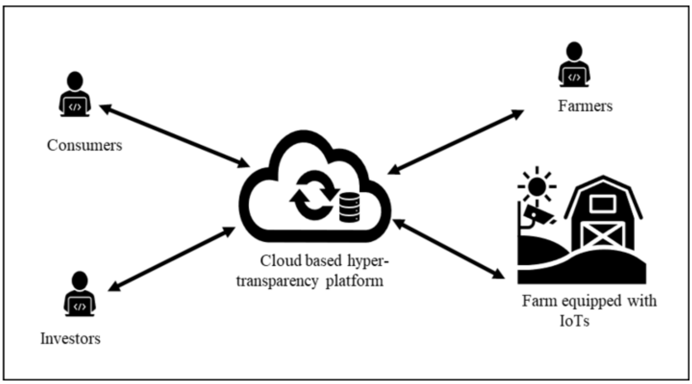

Figure 5. Infrastructure schematic and high-level software architecture.

We envision a communication module where consumers can ask questions to the farmers in real-time about the farm activities. This will allow both parties to not only engage but to clarify potential miscommunications. Farmers are generally busy people and it is hard for them to spare time to communicate with consumers. Realizing this, we propose an Artificial intelligence-based (AI) control system as shown in Figure 6.

An AI control system is equipped with text-to-voice, voice-to-text and Natural Language Processing technologies. Consumers can ask question in both voice and as written text; this will be received by the AI control system. This system will process the content in real-time to check for any abusive behaviour. Questions will be delivered to the famers as voice, which they can listen to via a headset and can answer by voice or text. Subsequently, the AI control system transfers the answer back to the consumer.

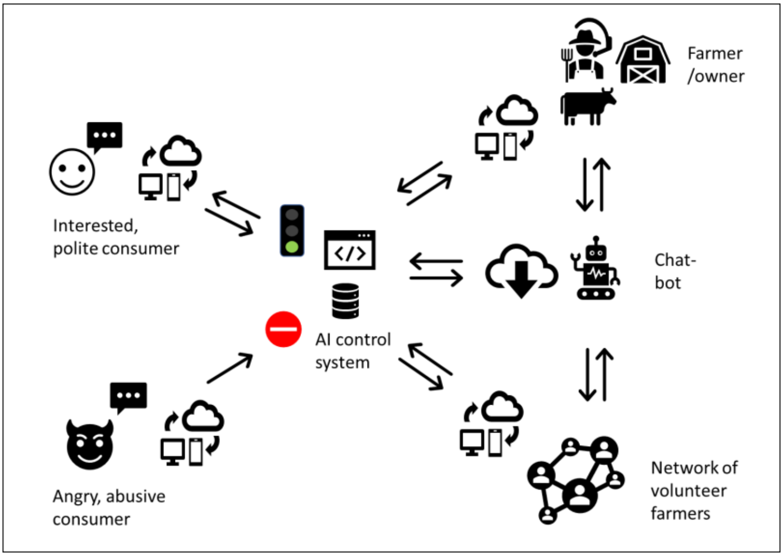

Figure 6. Overview of communication module.

3. Transdisciplinary Development Process

The problem of designing a SIMS is a genuine transdisciplinary challenge, requiring expertise in areas such as data science, robotics, supply chain management, engineering, sensor technology, and economics. With that in mind, the team developing the SIMS was selected based on both the depth and breadth of their knowledge. The core team consists of three people, all of which have a T-shaped skills set, with depth in expertise in at least one of the above-mentioned areas, together with a broad set of interests in other areas. The SIMS-project forms part of a larger program, “NZBIDA”[2], which is dedicated to harnessing the power of digitalization to transform the New Zealand agri-food sector. In the program, about 70 people from a wide range of disciplines participate. Expertise from that pool of people is consulted by the core “SIMS-team” as when required.

[2] New Zealand Bioeconomy in the Digital Age.

The core team is directly responsible for development of four out of the five modules of the SIMS. The exception is the “post-farm gate” module, where the methods for gathering verifiable information about product attributes at the processor stage of the supply chain are developed by another team within the NZBIDA program (the “food authentication” team). One member of the food authentication team functions as a liaison between the two teams and in this way helps to promote collaboration.

As in any transdisciplinary project, there have been challenges. Team-members have had to educate themselves in certain areas and have had to “develop” common concepts and language through which they could efficiently communicate with each other. Also, while there was an abundance of specialized, talented people within the NZBIDA program, comparatively fewer of them also had the T-shaped skills that make transdisciplinary collaboration function more smoothly. This made communication within the wider program sometimes challenging.

Transdisciplinary collaboration requires both the ability and willingness of people to learn new skills and to broaden their horizon. This takes time and much commitment. In that sense, transdisciplinary collaboration is less like some switch that can be turned on and off (depending on the nature of the problem), but more like muscle that needs to be developed through years of cultivation. The effort it takes to be able to contribute to a transdisciplinary project cannot be taken for granted, or this leads to suboptimal results.

4. Discussion and further work

The use of traditional transparency schemes, with their reliance on indirect and uni-directional information flows is unlikely to increase consumer trust in producers and food sellers. Consumers mostly have a transactional relationship with producers and food sellers that is unlikely to change in a meaningful way through the adoption of such schemes. However, hyper-transparency schemes have the potential to change the nature of that relationship to a degree, by facilitating more direct interaction between producers and consumers. In this way, they could bring producers and consumers closer together.

In the present paper we have presented the design of a SIMS to support smallholders in the agri-food sector to implement a hyper-transparency scheme and we have discussed its transdisciplinary development process. Both the design and development process of a SIMS need to factor in not only consumers potential disinterest in the possibilities hyper-transparency schemes bring (by presenting information to the consumer in an engaging fashion), but also how to deal with the potential unwillingness of the larger players in the supply chain to support and participate in these schemes. Especially, companies operating at the processing stage of supply chains traditionally have been unwilling to incur additional costs in separating product flows and of sharing sensitive information with their suppliers. A couple of methods were discussed that could help smallholders to reduce or bypass this problem: (1), technologies that enable farmers to undertake some processing activities already at the farm-level); and (2), the use of novel sensor technology that is linked to the SIMS and that can help to dramatically reduce the time and costs of keeping track of the origin of food products.

Hyper-transparency schemes and associated SIMS could become another tool for lead-companies to use for the purpose of further exerting control over their supply chains. However, they could also become a tool that empowers more smallholders to develop and set-up their own supply chains, through which they can market their own, products.

These two futures are not mutually exclusives. To help ensure that SIMS will serve both types of purposes, we are developing the system described here.

Acknowledgement

This project is part of the New Zealand Bioeconomy in the Digital Age program, funded by the Ministry of Business, Innovation & Employment.

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