building 4.0 crc

# #2: Automated tracking of construction and materials for improved supply chain logistics and provenance – Scoping study

## FINAL REPORT – EXECUTIVE SUMMARY

THE UNIVERSITY OF MELBOURNE

MONASH University

QUT

Australian Government
Department of Industry, Science and Resources
AusIndustry
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# EXECUTIVE SUMMARY

The construction supply chain is a critical enabler for the construction industry but also poses challenges and risks. This is mainly due to the typical make-to-order nature of the construction supply chain, which is often unstable, highly fragmented, and geographically dispersed. The ability to track and trace, called traceability, is becoming increasingly important as it contributes to building compliance, project efficiency, safety, sustainability, and performance. This scoping study aims to understand the state-of-the-art traceability in the construction industry and key stakeholders' perspectives and recommend future research. The longer-term objective is to demonstrate how sensor networks can be used to provide live streamed data to improve project management and validate building compliance through measures used to guarantee the provenance of the supply chain. Systems to be developed will have the further capability of integration with the digital twin of the building.

To achieve this, we have assembled a multidisciplinary research team from the University of Melbourne, Monash University, and Queensland University of Technology with close collaboration and engagement with industrial partners. The researchers have used a mixture of research methods (e.g., interviews, literature review, and case studies) to assess existing and emerging tracking technologies (e.g., sensors, visual tracking, information systems, data collection) for sectoral and issue appropriateness. The project has been decomposed into eight tasks, and the key research findings are summarised below.

**Traceability Lessons Learnt from the Food Industry**

Traceability in the food industry is largely driven by safety and quality, which is the primary concern of any food business today. We have seen other benefits of developing traceability capability, such as optimizing process efficiency, improving sustainability performance, and increasing consumer confidence. Comprehensive legislation, regulations, and international standards mandating traceability exist in the food industry. Although the legislative requirements only demand minimal information and can be fulfilled even with a paper-pencil approach, some sectors (e.g. red meat) take an extra step and rely on full digitalisation and a centralised database. GS1 plays a pivotal role in traceability, providing standards for identifying, capturing, sharing, and using information related to a product. The GS1 12 Identification Keys contains information describing the critical tracking events, including the who, what, where, when, and why. Those ID keys can be carried with mature technologies like barcodes, RFID, and QR codes. Advanced digital technologies (e.g., IoT and Blockchain) are still under development for traceability applications where the cost is the main barrier to adoption. Furthermore, the slow adoption of digital traceability is also attributed to technological, operational, and cultural obstacles.

**Supply Chains in Building Design, Construction, and Operation**

Chapter 3 begins by identifying several areas where supply chains in building projects differ from other industries. These are (i) the complexity and inter-related nature of construction projects and their legal context, normally undertaken by a temporary consortium of firms, (ii) unique activities such as excavation, where the "supply activity" is a removal activity, (iii) the active role of the Demand Chain participants in checking and approving the results of Supply Chain activities, (iv) the heavy use of all of a flexible mix of “supply only”, “service only” and “supply and service” subcontracts and (v) the role of the lead contractor (construction systems integrator) in creating and managing a production facility which can change dramatically throughout the single contract. The discussion follows the RIBA Plan of Work 2020, using a simple example of an aluminium door assembly to relate the content to a simple example. Comments on the impact of Demand Chain and Supply Chain concepts on the development of BIM (Building Information Modelling) are presented, along with comments on the value of BIM in improving Supply Chain practice. It is worth noting that BIM can act as a “repository” for storing some results of demand chain management. The ISO 19650 series of standards cover the current requirements for integrating BIM into building projects. However, many things are not captured in BIM, such as regulatory requirements and temporary works, so BIM is likely to remain a useful adjunct to demand chain and supply chain management for the foreseeable future.

**State-of-the-art in Sensor Technology for Product Identification and Tracking**

The current sensors and associated technologies have advanced over the years. The suite of sensor technologies can enable traceability in most scenarios. However, some specific challenges are highlighted in the next section. Generally, we can integrate technologies with common standards into an integrated suite for material tracking and construction processes. Although most technologies have some standards, there could be a few proprietary technologies that need integration with mainstream technologies for easy integration and interoperability of data flow and tracking. The available technologies are relatively advanced, and the commercial solutions would easily cater to most construction processes. In addition, the commercial solutions are flexible and can be integrated into existing technology platforms on a need basis. Some advanced barcoding and RFID technologies for extreme conditions (labels available for temperatures up to 1370°C, resistant to chemicals) are primarily suitable for manufacturing and tracking materials. However, cost and associated factors may limit organisations from adopting such technologies. Most of these labels are produced using specialised printers and can be purchased for long-term benefits. We can have real-time tracking information available on smartphones and dashboards by combining multiple sensors (such as GPS, cellular communications, barcode, RFID, and other specific sensors). The comparison between various sensor technology solutions for traceability is presented in figure 1.

**State-of-the-art in Logistics and Construction Onsite Tracking**

The uniqueness of onsite material tracking warrants a comprehensive review of the literature. Thus, chapter 5 utilizes a hybrid literature review method to investigate the state-of-the-art of onsite material tracking. This task first summarises the applications of tracking technologies on the construction site with a bibliometric analysis, providing the audience with contextual information on the technologies and tracked objects. A critical review of onsite material tracking follows, with details of data capture and integration. Three tracking strategies have been developed, which describe the flow of tracked materials from different perspectives by tracking materials, the material handling equipment, and installed building elements. In addition to technological details, this task also scrutinises the linkage between sensors and construction management tasks and the evolution from sensor-captured data to operational insights on productivity, safety, and quality.

| | QR Code | Barcode | Active RFID | Passive RFID | NFC | BLE | GPS |
|---|---|---|---|---|---|---|---|
| Cost-Effective | $ | $ | $$$ | $ | $$$ | $$$ | $$$ |
| Real-time tracking | ⊘ | ⊘ | ⊘ | ⊘ | ⊘ | ✔ | ✔ |
| Power Consumption | ⊘ | ⊘ | ✔ | ⊘ | ✔ | ⊘ | ✔ |
| Scanning Range | High | High | High | Low | Low | Low | Unlimited |
| Storage capacity | 3 KB | > 100 bytes | 2 KB | 4-8 KB | 48 Bytes – 8 KB | NA | Unlimited |
| Continuous scanning | ✔ | ✔ | ✔ | ✔ | ✔ | At regular intervals | Real-time data |
| Two-way Communication | ⊘ | ⊘ | ⊘ | ⊘ | ✔ | ✔ | ✔ |
| Labour Intensive | ✓ | ✓ | ✓ | × | ✓ | ✓ | ✓ |
| Popularity | Very high | Very high | High | High | Moderate | Moderate | Moderate |

*Figure 1: Comparison of sensor technology solutions*

Despite the prominence evidenced by technology advancements, automated, sensor-based onsite material tracking still faces various challenges, which can be categorised into (1) technological challenges (e.g. many technologies require tedious setup, frequent sensor repositioning for unblocked line-of-sights), and 2) implementation challenges (e.g. design models, schedules, site layout plans, are essential information for material tracking onsite but often not available in an integrated information platform).

**State-of-the-art in Information Management Systems and Blockchain Technology for Traceability**

In chapter 6, we have tried to address the following research questions: 1: What are the weaknesses in existing information systems; 2: What are the challenges for blockchain technologies in the supply chain? 3: How does blockchain technology change the CSC, and in which aspect or dimension? 4: Apart from the present use cases, what more uses and research streams are possible for blockchains in the CSC?

BIM and Enterprise Resource Planning (ERP) systems are the most relevant information platforms for collecting, reporting and sharing product traceability information. However, one-to-many, many-to-one, and many-to-many object correlations apply across the supply chain processes, further compounding the meaning, perspective and scope of traceability. The supply chain suffers from multiple issues, such as late payments, low transparency in locating materials, and data interoperability. While blockchain technology is still under development, permissioned blockchains are potentially applicable for time-sensitive applications in the construction supply chain for traceability, transparency, decentralisation, immutability, smartness, and privacy. Three types of blockchain applications are most promising for traceability: 1) tracking, 2) contracting, and 3) transferring.

**Stakeholder's Perspectives: Drivers & Barriers**

This study aimed to identify the drivers/benefits and barriers/challenges of implementing digitalisation for the construction supply chain traceability. Based on data collected through semi-structured interviews with experts (academics, practitioners, and stakeholders), we consolidated 79 elements, 44 of them drivers/benefits and 35 barriers/challenges. Out of those, 22 elements (13 drivers/benefits and 9 barriers/challenges) were assessed as highly critical for a successful digitalisation of the traceability systems. Please refer to figure 2 for the summary of these elements showing the linkage between drivers/benefits and barriers/challenges. Experts deem the drivers/benefits that promote real advantages to current traceability practices and systems more prominently. When considering the barriers/challenges, the degree to which the digital traceability's results are visible to the adopters seems to be an important issue, being able to impair the digitalisation of the construction supply chain. It is worth mentioning that some highly critical drivers/benefits (e.g., enhanced supply chain collaboration and greater supply chain transparency) may only be fully achieved if the entire construction supply chain engages in traceability digitalisation. At the same time, some barriers/challenges (e.g., short-term relationships and unbalanced risk across the supply chain) may be inherent to how the construction supply chain is designed and, hence, more difficult to overcome.

Furthermore, companies that already have some initiatives towards the digitalisation of the construction supply chain traceability (early adopters) may be able to understand and visualise the drivers/benefits and barriers/challenges more than others that have not started yet (late adopters). This suggests that the more companies advance in traceability digitalisation, the more aware they will become regarding its drivers/benefits and barriers/challenges. Nevertheless, both early and late adopters perceived some highly critical drivers/benefits and barriers/challenges equally, which may indicate their greater relevance for such digitalisation.

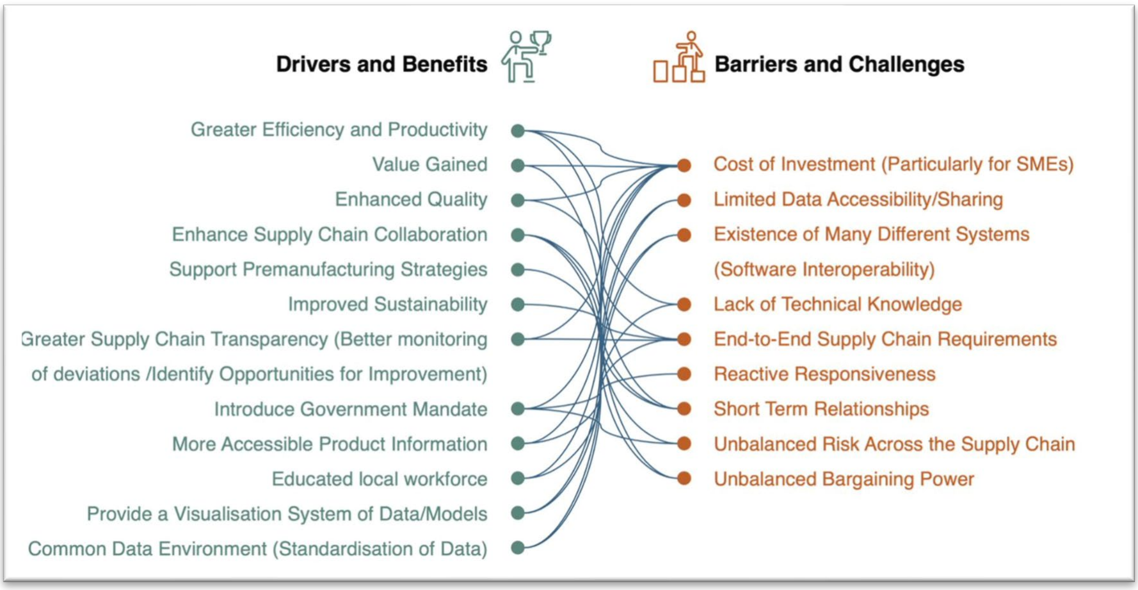


*Figure 2: Drivers/ Barriers of adopting digitalisation in the construction industry*

**Case Studies**

Traceability technology potentially offers the opportunity for building companies to semi-automate select processes that have been traditionally manual and improve access to real-time information (of improved quality) to inform project decision-making. Chapters 9-11 provide a summary of recommendations from the case analysis, highlighting the potential benefits of adopting traceability technology.

We also highlight opportunities for improving business process efficiency via this type of technology for Henley building operations, providing support for future research in this area. This may take the form of a more detailed analysis in trialling various technological solutions to improve efficiency in processing building product information on site (e.g., barcoding or RFID labels/tags). It also supports the possibility of extending the scope of research to capture upstream supply chain processes and track timber provenance/origin information in verifying sustainable timber sources. Although these recommendations apply to Henley operations, general experiences in the procurement, delivery and installation of prefabricated building components on site are not unique. As such, these recommendations may apply more broadly to other leading residential builders similar to Henley Homes.

One of the key issues highlighted in the BlueScope case study is that there is a lack of standardisation across the members of supply chains, particularly for the welded beams. Despite all information being linked to the test certificates, differing product identification numbers are used between the manufacturer and the final site positions. Using barcoding or chips in the steel may improve the tracking and tracing of the products through an integrated solution. Still, challenges lie in the cutting or altering of the products as well as galvanisation if it’s required. There are further difficulties in identifying the welded beam section, which comprises three different plates that are likely to have slightly different chemical attributes and strengths.

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