MANUFACTURING TRACEABILITY AND PROCESS MANAGEMENT

From Serial Number to Traceability: A Qualitative Case Study of Marking, Record-Keeping and Process Documentation in a Security Seal Manufacturer

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Abstract

Tamper-evident security seals are low-cost products whose value depends on a unique serial number. This paper examines how marking, record-keeping and process documentation work together to turn that number into usable traceability in a small Indian manufacturer. It uses a qualitative single-case design and draws on participant observation during an internship from 22 June to 30 July 2026 at SKM Innovative Techno Products Pvt. Ltd., Dombivli, where the author supported injection moulding and laser marking work, made client billing entries, helped track serial numbers by bag, drafted operator standard operating procedures (SOPs) and mapped business-to-business clients. Thematic analysis of field notes produced five findings. Permanent laser marking makes set-up the critical control point. Serialization alone does not give traceability unless the serial records are linked to billing. Manual record steps are the main source of mismatch risk. Written SOPs reduce dependence on verbal knowledge. Client needs differ by industry. The paper offers three propositions for later testing and practical suggestions for small seal manufacturers. The findings are exploratory and limited to one firm and to the areas in which the author worked.

Keywords: security seals; traceability; serialization; laser marking; standard operating procedures; small manufacturers; India

1 Introduction

A tamper-evident security seal does not stop anyone from opening a bag, a meter box or a shipping container. It shows whether the item has been opened. Seals are used in logistics and courier work, container shipping, utilities, cash-in-transit, chemicals and agriculture, and the global market for them has been estimated at about US$1.1 billion in 2022, with growth to about US$2.4 billion expected by 2031 (Transparency Market Research, n.d.). Demand rises with trade, e-commerce and the inclusion of seals in supply chain security standards.

A seal is useful only if its identity can be trusted. Each seal normally carries a unique number, and often a client logo and a barcode. If the number is wrong, unreadable or not recorded, the seal loses most of its value to the client. This makes the link between marking and record-keeping central to the quality of a seal manufacturer, even though the product itself is small and simple.

Practitioner writing on traceability tends to use examples from sectors with strong safety or regulatory pressure, such as automotive, aerospace and medical devices (Brady, no date; Keyence, n.d.). In the sources reviewed for this paper, there was little description of how a small manufacturer

of low-cost, high-volume items keeps its marking, records and billing consistent. This paper tries to give one such description from the inside.

The topic is useful for practice and for study. For practice, it points to inexpensive controls that a small plant can adopt. For study, it gives a worked example of the difference between serialization and traceability in a setting where the product costs very little but the information on it matters a great deal.

The study asks three research questions.

1. RQ1: How does the permanence of laser marking shape control practices in seal production?
2. RQ2: How are serial number records linked to billing, and where can that link break?
3. RQ3: What role do written procedures play in keeping marking and record work consistent?

The paper is organised as follows. Section 2 reviews the literature and sets out a simple conceptual framework. Section 3 explains the method. Section 4 presents the findings, Section 5 discusses them and states three propositions, and Section 6 concludes.

2 Literature review and conceptual framework

2.1 Security seals and standards

Seals are made in plastic, metal and cable forms and are sold as single-use or reusable items (Transparency Market Research, n.d.). The standard ISO 17712 groups mechanical seals for freight containers into indicative, security and high-security classes and describes how they are tested (ISO, 2013). The classification shows that a seal is judged both on its strength and on how clearly it reveals tampering. The wider market for tamper-evident packaging has also been estimated to be growing, with India named as an area of significant growth (Global Market Insights, 2024). Different research firms report different values because they define the market differently, so such figures are best read as indicators of direction.

In India the sector includes many domestic manufacturers. Business listings show, for example, that Yash Seals Pvt. Ltd. describes itself as a maker of plastic, metal, bolt and padlock seals established in 2002 (Yash Seals Pvt. Ltd., n.d.), and Secure Seals (India) Pvt. Ltd. describes itself as a Mumbai-based manufacturer and exporter established in 2003 (Secure Seals (India) Pvt. Ltd., n.d.). These are self-descriptions and are used here only to show that clients can choose among several local suppliers, so quality, marking accuracy and delivery time become ways to compete.

2.2 Injection moulding

Injection moulding is a cycle of clamping the mold, injecting melted plastic, cooling and ejecting the part (Groover, 2020). Machine settings such as temperature, pressure and cooling time affect output and quality, and wrong settings can cause defects such as flash or incomplete filling (Rosato et al., 2000). Many such defects can be seen and the part rejected, which becomes important when this stage is compared with marking.

Plastic seals are commonly made from engineering polymers such as polypropylene or ABS, and metal parts are used where more strength is needed. Automatic machines repeat the cycle with little manual handling, so the operator's attention shifts to supplying material, checking parts and reacting

to problems. Because the part can be seen after each cycle, the quality check at this stage can be made by looking at it.

2.3 Laser marking and direct part marking

Laser marking is a non-contact method that makes a permanent mark by changing the surface of a material (Steen and Mazumder, 2010). Industry sources describe direct part marking as a way of placing a permanent identifier on the product itself, so that it can be tracked through its life, and note that laser marks are not easily altered or removed like labels (Brady, no date; Keyence, n.d.). The permanence that makes the mark trustworthy also means that an error in the mark cannot be corrected later.

Fibre lasers are widely used for metals and can mark many plastics, while UV lasers make fine marks on plastics with little heat (Steen and Mazumder, 2010). The operator designs the text, logo, barcode and serial series in control software, and the series can increase automatically from one item to the next. This software step is where design errors can enter, and it is separate from the physical marking.

2.4 Serialization and traceability

Keyence (no date) separates serialization from traceability. Serialization means giving each item a unique number. Traceability exists only when that number is read along the process and linked to other data, so a serial number without linked data does not allow a cause to be found. The same source also distinguishes lot-level from part-level traceability, which differ in marking effort and in the scope of any recall. Brady (no date) describes serialization as assigning a unique identifier so that a product can be traced back to a database of information about it. Chopra and Meindl (2019) argue more generally that accurate shared information reduces errors and cost across a supply chain.

For seals that are packed in bags and sent to clients in series, a practical level of record-keeping sits between lot and single item: the bag and its serial number range. This paper calls it bag-level recording and treats it as the working unit of traceability in the case studied.

Granularity matters because it decides how much has to be marked, read and stored. Marking every single item into a database gives the finest traceability but needs reading equipment and data storage. Lot-level records need less effort but cover wider groups when something goes wrong (Keyence, n.d.). A low-cost product such as a seal may reasonably sit between the two.

2.5 Standardisation and written procedures

Slack et al. (2022) discuss how standard methods keep an operation's output steady, so that results do not depend on the memory or habits of one person. Ohno (1988) treats standardised work as a base on which improvement is built. An SOP is the written form of such a method, and its usefulness depends on being short, clear and followed.

Written procedures are also a way of keeping knowledge in the firm when staff change, which matters in plants that rely on a few experienced operators. Short procedures are easier to read and to update than long manuals, which is why the drafts in this case were kept brief.

2.6 Conceptual framework

The framework used here treats the work of a seal manufacturer after moulding as a chain of three links: marking, recording and billing, held together by written procedures. Table 1 states the control question for each link and what goes wrong without it.

Table 1. Conceptual framework.

Link	Control question	Possible failure
Marking	Is the right logo, barcode and number on every seal?	Unusable seals, because a permanent mark cannot be corrected.
Recording	Is the serial number range recorded by bag and by order?	A missing or repeated number cannot be traced.
Billing	Does the bill agree with what was made and sent?	Disputes with the client and errors in the accounts.
Procedures	Are the steps written down and followed?	Results depend on who is operating the machine.

3 Methodology

3.1 Research design

The study is a qualitative single-case study. A case design suits the research questions because they ask how and why things work inside a real setting (Yin, 2018), and single cases can be used to build early ideas that later work can test (Eisenhardt, 1989). The aim is description and explanation, not statistical generalisation (Kothari, 2004).

3.2 Setting and role

The case is SKM Innovative Techno Products Pvt. Ltd., a business-to-business manufacturer and exporter of tamper-evident security seals in Dombivli, Maharashtra. The firm molds plastic seals in its own plant, assembles the locking parts and marks client logos, barcodes and serial numbers with fibre or UV laser machines. The author worked there as an Assistant Operations Manager Intern under the Operations Manager from 22 June to 30 July 2026. This position allowed participant observation: the author took part in some of the work and watched the rest.

3.3 Data sources

Table 2 lists the data used. All of it comes from the author's own work and notes. No cost, production or sales figures are reported, because the firm treats them as confidential.

Table 2. Data sources.

Source	What it provided
Field notes and weekly activity sheets	A record of tasks, observations and learning across six weeks.
Observation of the molding and laser lines	How the cycle runs, how marking is set up and checked.
Billing and bag-record entries handled	How orders, quantities and serial ranges are recorded and billed.
Draft SOPs written by the author	The steps that operators need, and how clearly they could be stated.

Source	What it provided
Discussions with the Operations Manager and operators	Explanations of how the work is done.
Books, standards and industry sources	Concepts used to interpret the observations.

3.4 Analysis

The field notes were read several times, coded by task and then grouped into themes, following the steps of thematic analysis described by Braun and Clarke (2006). The themes were then compared with the framework in Table 1. Each finding in Section 4 rests on observations from more than one task, which gives some triangulation within the case.

3.5 Limitations of the method

The study has one firm, one observer and about five and a half weeks of data. The author was a student with limited technical background and was also a participant, so what was noticed may be shaped by the tasks given. The effect of the SOPs on performance was not measured. The results should therefore be treated as exploratory.

3.6 Trustworthiness and ethics

To improve credibility, each finding is tied to a specific task and to more than one observation, the draft SOPs were prepared for review by the Operations Manager, and the limits of the data are stated openly. The study does not claim that the findings apply to other firms. On ethics, the author collected no personal data from clients or staff. Client names, costs, volumes and prices are not reported, and the Operations Manager is named only as the person who supervised the work.

4 Findings

4.1 Marking is the critical control point

Moulding errors such as incomplete parts can often be seen and rejected, and the part can be molded again. Laser marking works differently, because the mark is permanent. A wrong starting number, a misplaced logo or an unclear barcode means that the marked seals cannot be used for that client. The author's work on editing client logos and on the basic set-up of the laser machines made this clear. The work depends on loading the correct design file, placing the seal so that the mark falls in the right place, and checking a sample before the full run. In terms of the framework, the marking link needs its checks before the work starts, not after.

Logo editing is a design task as well as a machine task. The logo has to fit the space on the seal and stay clear after marking, and a small change in size can affect how easily it is read. The practice learned was therefore to check the file on the screen and again on a sample seal before the full marking run.

4.2 Serialization is present, but traceability depends on linking

Every seal in the case carries a serial number, so serialization exists. What turns it into traceability is the record of which numbers are in which bag and which bag went to which client. The author's task of tracking bag serial numbers was the clearest example. If a client asks about a missing or repeated number, the answer is found in the bag record. The record is also what lets the quantity be checked

before billing. This supports the distinction made by Keyence (no date): a number without linked data does not allow a cause to be found.

The bag-level record has two uses. It answers client queries, and it supports the quantity check before billing. It appears that a bag record that is not updated at the time of packing would be hard to rebuild later, so the timing of the entry matters as much as its accuracy.

4.3 Manual steps are the main mismatch risk

The billing entries and the bag records join production to accounts. The quantity on the bill should agree with the quantity made and sent, and the number ranges should agree with the bags. Wherever such entries are made by hand, a slip in a number or a quantity can create a mismatch that is found only when a client queries it. The practical safeguard the author used was to check each entry against the physical bag and the series before moving on. This was slow, which suggests a case for a more structured register.

Three kinds of mismatch seem possible: a wrong quantity, a wrong number range and a wrong client. Each could be caught by a simple cross-check before billing. This is an assessment of risk drawn from the author's own handling of entries and not a measured error rate.

4.4 Written SOPs reduce dependence on verbal knowledge

The author drafted simplified SOPs for an automatic moulding machine and for the laser machines. The drafts used short numbered steps, plain words and a check at the end of each stage, and were intended to be reviewed by the Operations Manager before use. Writing them showed how much of the machine routine is learned by watching, and how hard it is to state a step so that someone who has not seen the machine can follow it. The expected benefit is that a new operator depends less on spoken instructions. The study did not test whether the SOPs achieve this.

A useful SOP at this level has a purpose, safety points, numbered steps, checks and a record to fill. The drafts followed this layout. Review by the Operations Manager mattered, because a procedure written by a new intern needs to be checked by someone who knows the machine.

4.5 Client needs differ by industry

The author grouped the firm's business-to-business logistics clients by industry. Courier and logistics firms, container users, utilities and banks tend to need different seal types and marking details. This affects planning, because different seal types and markings mean different set-ups on the laser machines and different records to keep. A client map therefore supports both production planning and follow-up with clients.

Client mapping also showed the value of keeping simple records of each client's seal type and marking needs, because repeat orders can then be set up in the same way each time.

4.6 How the findings connect

The five findings are connected. Because marking is permanent (4.1), the numbers on the seals must be recorded exactly (4.2). Since records are made by hand (4.3), written procedures (4.4) and simple checklists are needed to keep entries consistent. The client map (4.5) then shows where these controls matter most, for example for clients who need every number accounted for. Table 3 shows which task supported which finding.

Table 3. Tasks, findings and framework links.

Task during the internship	Finding supported	Framework link
Logo editing and laser set-up	4.1 Marking is the critical control point	Marking
Tracking bag serial numbers	4.2 Linking gives traceability	Recording
Billing entries	4.2 and 4.3 Linking and manual risk	Billing
Drafting SOPs	4.4 Written procedures	Procedures
Client mapping	4.5 Client needs differ	All links

5 Discussion

The findings suggest that in a small seal manufacturer the quality problem is less about making the seal than about the chain after moulding. The contrast between moulding and marking in Section 4.1 fits the general idea of preventing errors where they start (Slack et al., 2022). A visible moulding defect can be rejected, whereas a permanent marking error is only found after the seals are marked, so checks need to move to before the run.

Section 4.2 adds a practical point to the serialization and traceability distinction. In this case the unit that matters is the bag, not the lot or the single seal. Bag-level records give a manageable level of traceability for a low-cost product, because marking every seal into a database would cost more than the product justifies. The weak point is the link between those records and billing, and manual entry is where that link is most likely to break.

The findings agree with the general view in the literature that identity data has value only when it is linked to other records (Keyence, no date; Chopra and Meindl, 2019). They differ from the practitioner examples in the level of technology. The plant in this case relies on simple records and small checks, not on automated reading systems. This suggests that for small manufacturers improvement may begin with discipline and documentation, before any investment in systems.

The contribution of the paper is modest. It gives a description of the chain after moulding for a low-cost product, a bag-level view of traceability and three propositions for testing.

The case leads to three propositions that later studies can test.

Table 4. Propositions for future research.

No.	Proposition
P1	In permanent-marking operations, firms that verify the design file and a sample mark before a full run will have fewer unusable marked units than firms that do not.
P2	Firms that reconcile serial number records with billing before invoicing will resolve client queries on missing or repeated numbers faster.
P3	Short, written, step-by-step SOPs will reduce differences in machine set-up between operators compared with verbal instruction alone.

For practice, four suggestions follow from the findings.

1. Use a short pre-run checklist for laser marking that covers the logo file, the starting number, the mark position and a sample mark, signed by the supervisor.

2. Keep one digital register of serial number ranges by order and by bag, and match it with the billing entries before an invoice is raised.
3. Review and adopt the simplified SOPs, display them near the machines and update them when settings change.
4. Keep a client database by industry, with seal types, order pattern and contacts, to support planning and follow-up.

6 Conclusion, limitations and future research

This paper described how marking, record-keeping and process documentation work together in one small Indian seal manufacturer. Answering the research questions, the permanence of laser marking moves control to the set-up stage (RQ1). Serial number records give traceability only when they are linked to billing, and that link is most exposed where entries are made by hand (RQ2). Written procedures are a simple way of keeping set-up and record work consistent across operators, although their effect was not measured here (RQ3).

The study has clear limits. It covers one firm, one observer and a short period, and it reports no quantitative data. Future work could test the propositions in Table 4 across several seal manufacturers, measure the share of marked units that are rejected before and after a pre-run checklist, or compare bag-level and item-level recording in terms of cost and error rate. Even with these limits, the case shows that for a product whose value lies in its number, the records around the number matter as much as the product.

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