Driving Digital Transformation in Precision Engineering: A Tooling Management Case Study

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***Abstract*—The precision engineering sector faces increasing pressure to enhance efficiency, traceability, and cost control, which are all challenges compounded by legacy systems and manual processes. This case study examines the digital transformation initiative of a UK-based Computer Numerical Control (CNC) precision engineering company, aimed at modernising tooling management. By leveraging low-code platforms, Azure cloud services, and real-time analytics through Power BI (Business Intelligence), fragmented paper-based systems are successfully replaced by integrated digital systems. The new system includes QR-coded tools, automated workflows, and centralised dashboards that enable traceability. This in turn enables actionable insights and continuous improvement. Some of the key outcomes of this transformation include improved data accuracy, reduced downtime, better cost tracking, and enhanced operator engagement. The initiative not only delivers immediate operational gains but also lays a foundation for advanced capabilities such as predictive maintenance and Internet of Things (IoT) integration. This transformation demonstrates how Small to Medium-sized Enterprises (SMEs) can adopt scalable, cost-effective technologies to drive innovation and competitiveness in a rapidly evolving manufacturing landscape. Furthermore, this case study highlights a scalable and generalisable approach that can inspire other companies and sectors in engineering to accelerate their own digital transformation journeys.**

Keywords*—*digital transformation; tooling management; Industry 4.0; CNC precision engineering; Power Platform.

I. INTRODUCTION

The manufacturing industry is undergoing a significant transformation driven by the need for higher efficiency, stringent quality assurance, and optimised operational costs. Precision engineering and CNC machining operations are challenged by complex tooling inventories, the need for traceability, and inefficiencies arising from manual tracking processes.

This paper addresses the following research questions: (1) How can low-code and cloud-based platforms digitise tooling management in a CNC precision engineering SME? (2) What quantitative improvements in accuracy and downtime result from this transformation? (3) How reproducible and generalisable is the proposed solution?

The emergence of Industry 4.0 technologies presents new opportunities to address these concerns [2]. Highly cited studies underscore the importance of data-centred approaches, such as Enterprise Resource Planning (ERP), IoT-enabled tool tracking, and real-time visualisation platforms [1]. Traditional paper-based workflows are increasingly recognised as impediments to productivity, contributing to errors, delays, and reduced responsiveness [3]. In contrast, cloud-based platforms, process automation, and integrated analytics redefine best practices in the sector.

This paper presents a case study from Bryken Ltd (a precision engineering company, Knowsley, UK). The case study details the company's digital transformation initiative focused on tooling management, covering streamlining of data capture, integration of disparate systems, and improvement of operational visibility, ultimately positioning Bryken for long-term resilience, innovation, and competitiveness.

The remainder of this paper is organised as follows. Section II presents the case study, describing the company context, the legacy tooling process and improvement criteria, the methodology and technologies adopted, the key performance indicators used for evaluation, and the resulting operational and financial impact. Finally, Section III concludes the work and outlines directions for future development.

II. THE CASE STUDY

A. Company Overview

Bryken Ltd specialises in the production of high-tolerance components for a range of industries including oil and gas, automotive, defence, and healthcare. The company operates a suite of advanced CNC machines and manages an extensive inventory of high-performance cutting tools sourced from multiple suppliers. Historically, Bryken relied on a combination of paper forms, spreadsheets, and manual operator input to track tool vending, usage, and return. This decentralised approach results in inefficiencies, frequent data discrepancies, and limited visibility into the real-time status of tooling across the shop floor.

The digital transformation initiative is launched to modernise tooling processes by implementing an integrated digital system capable of real-time data acquisition, automated reporting, and end-to-end visibility. The initiative seeks to eliminate manual paperwork, reduce tool-related downtime, improve inventory accountability, and enhance the accuracy of cost allocation per manufacturing order. This project is not just a technological upgrade, but a strategic move to future-proof Bryken's operational model.

The project is also aligned with Bryken's vision of moving toward data-driven manufacturing, where prior adoption of data-driven methodologies has been shown to benefit just-in-time production and continuous improvement metrics [4].

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B. Current Tooling Process and Improvement Criteria

To effectively address the tooling challenges, we began by conducting a comprehensive audit of the existing workflows, systems, and information processes. In the context of CNC precision engineering, the tooling process refers to the management of cutting tools used in machining operations, including their vending, allocation to machines, monitoring of usage, and return. Under the legacy approach, the process began with operators using paper-based first-off sheets to record tool usage for each new job. This manual documentation served as the initial point of reference for tool deployment. Next, operators would manually input job numbers associated with each tool transaction, linking the paper records to specific machining operations. Information from these sheets and operator entries was then fed into fragmented supplier reports, requiring supervisors to reconcile the data manually. Because there was no centralised or automated link between these steps, discrepancies could easily arise, from mismatches in operator entries to gaps between shop floor records and supplier data, making it difficult to maintain real-time accuracy and accountability throughout the tooling workflow. This resulted in frequent errors in job identification, lack of reliable cost allocation, and poor visibility of tool availability. Such inefficiencies affected the entire engineering process. For example, production downtime increased when tools were unavailable or unaccounted for, supervisors and procurement staff spent significant time reconciling data manually, and management struggled to forecast costs accurately. Collectively, these limitations reduced productivity, inflated operational costs, and undermined the company's competitiveness.

Figure 1 summarises the manual processes Bryken Ltd relied upon for tooling management before the implementation of the digital transformation initiative. As the figure shows, the workflow for tool usage and inspection followed a fully manual process. Step 1 involved recording first-off inspection results on paper sheets, with no digital linkage to job tracking systems. Step 2 required operators to manually enter job numbers, which often resulted in transcription errors and inconsistencies. Step 3 saw supervisors reviewing supplier tool usage reports by hand, delaying feedback and limiting visibility of performance data. Step 4 highlights the lack of automated data collection or cost tracking, making it difficult to monitor tool inventory and allocate costs accurately. Altogether, the figure illustrates the fragmented and inefficient nature of the legacy system, providing context for the need to transition to a fully integrated, digital workflow that overcomes these specific operational limitations.

Figure 1. Flow diagram of the pre-project tooling process.

The enhancement process starts by establishing the functional and technical requirements based on input from production operators, engineering leads, and procurement personnel. The collected feedback states the need to centralise and standardise tool vending data from multiple external suppliers, integrate machine-level tool usage with operator tracking, and replace multiple paper-based forms with a single unified digital interface. The required system should also support real-time monitoring of tooling costs per manufacturing order to offer granular traceability for root cause analysis, and it should facilitate customisable reporting for production and quality assurance teams. Key design criteria include user-friendliness, scalability, data integrity, and interoperability with existing Enterprise Resource Planning (ERP) and database systems. Importantly, the system should cater to users with varying levels of digital literacy and should integrate seamlessly with ongoing shop floor activities without introducing disruptions.

C. Methodology and Technology Used

The solution is implemented using a modular and scalable architecture based on Microsoft Power Platform and Microsoft Azure cloud computing services. As illustrated in Figure 2, the system follows a four-layer architecture: (1) Data Capture — QR codes on tools and first-off sheets at shop floor level; (2) Integration — Microsoft Power Automate for email parsing and workflow automation; (3) Storage — Microsoft SharePoint as the centralised data repository; (4) Analytics — Microsoft Power BI dashboards with custom Data Analysis Expressions (DAX) measures for real-time Key Performance Indicator (KPI) reporting. Several integrated systems and procedures have been implemented, as indicated below.

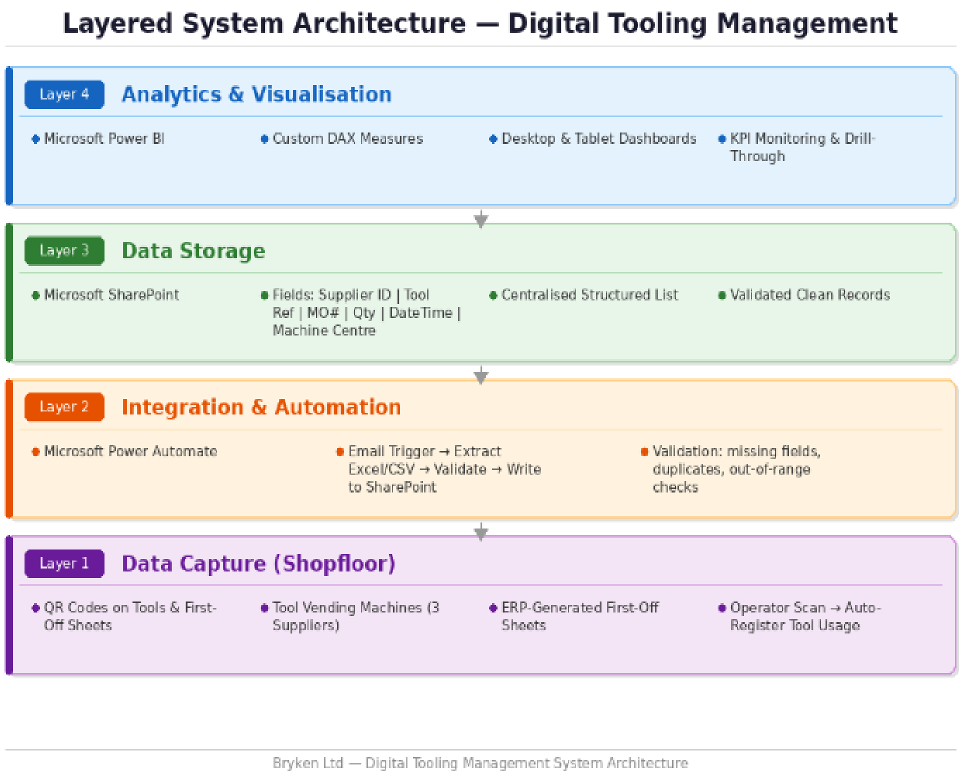
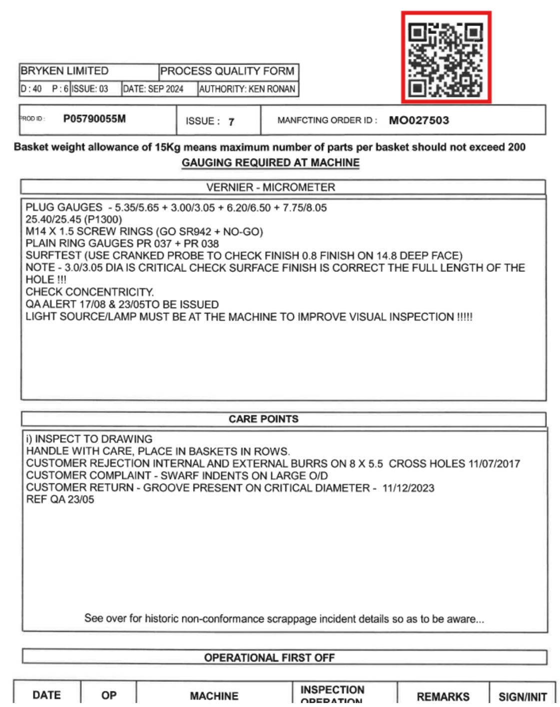


Figure 2. Layered system architecture of the digital tooling management solution.

C.1. Tooling QR Codes

First, QR codes are introduced to uniquely tag individual tools, enabling operators to scan and register tool usage with precision. Then, each first-off sheet incorporates a QR code which links each manufacturing order with its details containing tooling requirements, as shown in the example in Figure 3. The first-off sheet is a process quality document generated by the ERP system that accompanies every new manufacturing order. It contains inspection instructions, gauging requirements, and operator guidance. The sheet stays at the CNC machine that is used for the order and is kept handy until the manufacturing order is completed. Whenever tools are needed, operators scan the QR code of the sheet and the unique QR code of the required tool at the tool vending machine, which registers the tools used against that manufacturing order. In the legacy process, operators manually recorded job numbers and tool usage on the sheet, which often led to errors and inconsistencies. In the new system, the embedded QR codes allow operators and management to capture this information automatically by scanning, thereby eliminating manual entry, reducing errors, and standardising the recording of tool consumption across machines and shifts.



BRYKEN LIMITED	PROCESS QUALITY FORM
D : 40 P : 6 ISSUE: 03	DATE: SEP 2024 AUTHORITY: KEN RONAN

PROD ID : P05790055M | ISSUE : 7 | MANFCTING ORDER ID : MO027503

Basket weight allowance of 15Kg means maximum number of parts per basket should not exceed 200

GAUGING REQUIRED AT MACHINE

VERNIER - MICROMETER

PLUG GAUGES - 5.35/5.65 + 3.00/3.05 + 6.20/6.50 + 7.75/8.05
25.40/25.45 (P1300)
M14 X 1.5 SCREW RINGS (GO SR942 + NO-GO)
PLAIN RING GAUGES PR 037 + PR 038
SURFTEST (USE CRANKED PROBE TO CHECK FINISH 0.8 FINISH ON 14.8 DEEP FACE)
NOTE - 3.0/3.05 DIA IS CRITICAL CHECK SURFACE FINISH IS CORRECT THE FULL LENGTH OF THE HOLE !!!
CHECK CONCENTRICITY.
QA ALERT 17/08 & 23/05TO BE ISSUED
LIGHT SOURCE/LAMP MUST BE AT THE MACHINE TO IMPROVE VISUAL INSPECTION !!!!!

CARE POINTS

i) INSPECT TO DRAWING
HANDLE WITH CARE, PLACE IN BASKETS IN ROWS.
CUSTOMER REJECTION INTERNAL AND EXTERNAL BURRS ON 8 X 5.5 CROSS HOLES 11/07/2017
CUSTOMER COMPLAINT - SWARF INDENTS ON LARGE O/D
CUSTOMER RETURN - GROOVE PRESENT ON CRITICAL DIAMETER - 11/12/2023
REF QA 23/05

See over for historic non-conformance scrappage incident details so as to be aware...

OPERATIONAL FIRST OFF

DATE	OP	MACHINE	INSPECTION OPERATION	REMARKS	SIGN/INIT

Figure 3. An example of the new first-off sheet that incorporates a QR code for tool tracking.

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C.2. Tooling Inventory Record System

A crucial aspect of the operational process involves accurately tracking tool usage on the shop floor. Bryken currently works with three tool suppliers, each managing their own vending machines installed on site. These vending machines are owned by the tool suppliers and include an inbuilt computer system that records all tool vending activity. Whenever an operator vends a tool, the transaction is automatically logged in the supplier's system.

To facilitate internal monitoring and analysis, the tool suppliers automatically generate daily tool usage reports and send them to Bryken via email in Excel or CSV format. This timely and well-structured reporting ensures a clear record of inventory movements, which is essential for process improvement and operational efficiency. In the previous process, Bryken's supervisors manually opened each supplier email, reviewed the attached spreadsheets, and checked the tool usage information. This approach was time consuming, prone to human errors, and sometimes resulted in inconsistent data, making the information less reliable.

In the new system, the entire process has been automated. Power Automate detects incoming supplier emails, extracts the data from the attachments, applies validation checks, and uploads the verified data directly to SharePoint. The data schema captured per transaction includes Supplier ID, Tool Reference Code, Manufacturing Order Number, Quantity Vended, Transaction Date/Time, and Machine Centre ID. The Power Automate flow triggers on email receipt, extracts the Excel/CSV attachment, validates each row against defined field rules, and writes clean records to a structured SharePoint list. This automation removes manual work, ensures data accuracy, and provides structured information that is immediately available for analysis and reporting. Figure 4 illustrates the transformation from a manual, error-prone process of handling tooling reports to a streamlined and automated workflow using Power Automate.

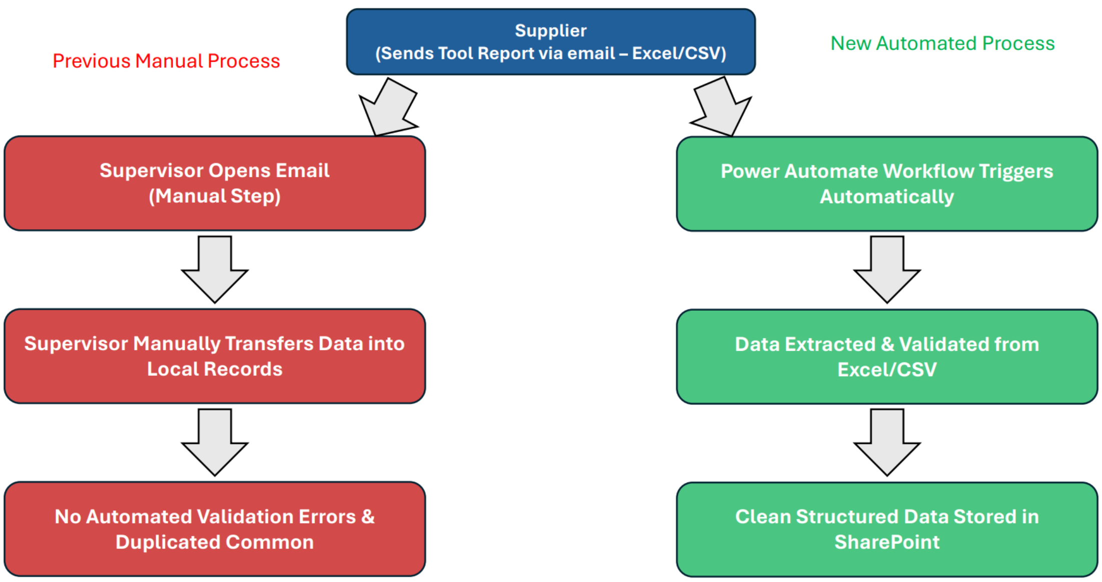

Figure 4. Tool usage report workflow (before vs. after).

C.3. Tooling Dashboard

Utilising information collected from the two procedures described above; a Tooling Dashboard is also introduced. Figure 5 illustrates an example of the new Power BI Tooling Dashboard, which provides an overview of tool usage and spending. The dashboard displays total tool expenditure, total manufacturing orders, quantities produced, product IDs, and the top five products with the highest tool costs. It also shows trends in tool usage over the past months. Dynamic filtering and interactive drill-through capabilities allow supervisors, production planners, and quality engineers to investigate anomalies and analyse information by machine, product, or date. Advanced DAX measures were used to create tailored key performance indicators, ensuring that the dashboards are optimised for both desktop and shop floor tablet use, enabling quick, data-driven decision-making. The design draws on best practices from early adopters of intelligent manufacturing shop floors [5].

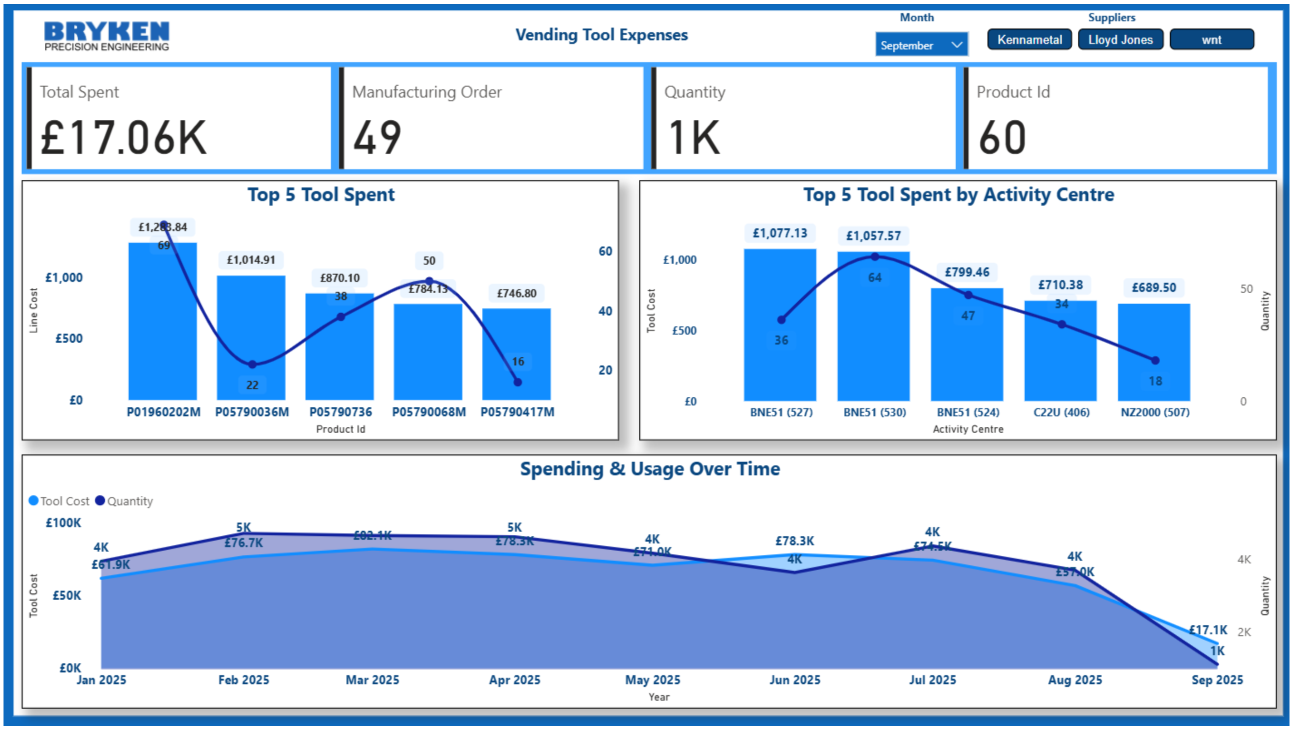

Figure 5. Overview of the Tooling Dashboard.

Figure 6 provides another screen from the Tooling Dashboard. The page provides a detailed breakdown of individual manufacturing orders, showing the tooling cost per product in both actual value and as a percentage of the selling price. This level of detail enables planners and management to understand product-level profitability, identify high-cost items, and make informed decisions to optimise tooling usage and production efficiency.

Tooling Cost Breakdown by Product

Manufacturing Order	Product Id	Completion Date	Quantity	Quantity Made	Quantity Scrapped	Tooling Price Per Part	Selling Price	Tool Percentage	Actual Tooling Cost
MO025987	P01530014M	12 November 2025	1,294.00	1,294.00	0.00	£0.05	£11.20	0.47%	£68.50
MO028700	P05790754	12 November 2025	702.00	702.00	0.00	£0.04	£1.44	2.57%	£25.95
MO028659	P05790784	12 November 2025	533.00	533.00	0.00	£0.59	£7.37	7.95%	£312.47
MO028799	P05791306M	12 November 2025	41.00	32.00	9.00	£2.82	£500.00	0.56%	£90.18
MO028858	P05980142M	12 November 2025	590.00	567.00	23.00	£0.46	£2.87	15.87%	£258.24
MO028418	P05160024	11 November 2025	885.00	881.00	4.00	£0.33	£9.92	3.37%	£294.53
MO028718	P05160026	11 November 2025	2,700.00	2,535.00	0.00	£0.07	£3.02	2.22%	£169.72
MO028287	P05790055M	11 November 2025	7,556.00	7,468.00	88.00	£0.64	£4.89	13.16%	£4,805.29
MO028373	P05790081M	11 November 2025	5,000.00	4,096.00	0.00	£0.09	£1.33	6.83%	£372.12
MO028672	P05790651	11 November 2025	370.00	370.00	0.00	£0.36	£11.67	3.11%	£134.23
MO028706	P05790680M	11 November 2025	400.00	396.00	2.00	£1.11	£23.35	4.76%	£439.80
MO028701	P05790691	11 November 2025	2,332.00	2,332.00	0.00	£0.10	£1.26	8.18%	£240.40
MO028457	P05791054M	11 November 2025	350.00	318.00	8.00	£5.20	£47.77	10.88%	£1,653.36
MO028906	P06570052M	11 November 2025	322.00	322.00	0.00	£0.27	£8.06	3.37%	£87.54
MO028886	P06570053	11 November 2025	403.00	403.00	0.00	£0.14	£9.17	1.53%	£56.50
MO028784	P00640075M	10 November 2025	650.00	536.00	0.00	£0.14	£4.90	2.78%	£72.98
MO028565	P03730003M	10 November 2025	584.00	584.00	0.00	£0.44	£8.42	5.24%	£257.57
MO028113	P05790146	10 November 2025	2,500.00	2,329.00	0.00	£0.01	£1.91	0.58%	£25.89
MO028270	P05790552M	10 November 2025	377.00	370.00	7.00	£1.10	£8.94	12.36%	£408.73
MO028432	P05790598M	10 November 2025	204.00	178.00	26.00	£0.20	£14.58	1.38%	£35.93
MO028759	P05790661M	10 November 2025	1,126.00	1,110.00	16.00	£0.58	£2.27	25.47%	£641.86
MO028658	P05790762	10 November 2025	994.00	971.00	23.00	£0.29	£1.80	15.97%	£279.05
MO028578	P05790874M	10 November 2025	507.00	498.00	9.00	£0.22	£3.58	6.24%	£111.19
MO028661	P05791014M	10 November 2025	145.00	142.00	3.00	£2.60	£38.54	6.75%	£369.67
MO028461	P05791216	10 November 2025	255.00	250.00	5.00	£0.30	£8.78	3.38%	£74.25
MO028840	P05790126	07 November 2025	1,576.00	1,576.00	0.00	£0.14	£1.56	9.17%	£225.45

Month: January, February, March, April, May, June, July, August, September, October, November, December

Figure 6. The Tooling Dashboard: breakdown of the manufacturing cost per product.

D. *KPI Definition and Measurement Methodology*

The following KPIs were defined and measured to evaluate the transformation.

(1) Stock Discrepancy Rate: the percentage of daily tool transactions where the quantity in the supplier's system did not match Bryken's internal records. A baseline was established over three months before implementation by manually cross-

referencing supplier Excel reports with paper first-off sheets, while post-implementation data was extracted from SharePoint automatically. The rate is calculated as:

Stock Discrepancy Rate = (mismatched records / total records) × 100%.

The baseline was approximately 18%; after implementation it fell below 4.5%, representing a reduction of over 75%.

(2) Tool-Related Downtime: the production time lost due to tools being unavailable or incorrectly allocated. Shift supervisors logged downtime events prior to implementation, whereas afterwards these were tracked via dashboard alerts. A reduction of approximately 30% was observed within the first three months.

(3) Tooling Cost as a Percentage of Selling Price: calculated per manufacturing order from Power BI, enabling profitability analysis at the order level. These figures are based on operational observations from a single site over three months and should be treated as indicative rather than statistically validated benchmarks.

E. Results and Impact

The deployment of the new digital tooling system brought significant improvements across Bryken's operations. Tool usage data has become readily accessible, enabling shift supervisors and engineers to identify usage patterns, detect anomalies, and take proactive measures to avoid tool shortages. The elimination of paper-based documentation led to an immediate reduction in administrative overhead and freed operator time for production activities.

Real-time tracking of tool consumption and availability allows job initialisation to be optimised and minimises tool-related delays. Operators have become more engaged in the tooling process, supported by intuitive interfaces requiring minimal training. Procurement teams also benefit from accurate consumption data, improving forecasting, reducing over-ordering, and strengthening supplier negotiations. The quantitative gains in stock-discrepancy and downtime reduction reported in Section II-D translate directly into these operational benefits. It is important to note, however, that the automated system does not eliminate errors entirely: the remaining discrepancies mainly stem from unavoidable operational factors such as occasional human errors in tool withdrawals, misplacement of tools on the shop floor, or delays in data updates from supplier systems. Nonetheless, the system significantly reduces these issues and enhances overall process reliability.

Crucially, the system also enables the identification of potentially unprofitable orders before production begins. One manufacturing order, with a quantity of 150 units, was analysed and revealed that the tooling required would cost more than the revenue generated from the sale. This insight prompted the implementation of a minimum order quantity of 3,000 units for that product, immediately preventing production of the unprofitable batch and avoiding unnecessary material and tooling costs.

These improvements represent not only a major operational gain but also a substantial financial impact. Reducing stock discrepancies ensures that procurement teams no longer over-order tools, preventing capital from being tied up in unnecessary inventory. Minimising downtime increases machine utilisation, translating into higher throughput and reduced lead times for customers. Accurate, real-time tooling data also helps the company provide better cost estimates and remain competitive.

The analysis of manufacturing orders shows that tooling consumption depends on the machining process involved. More complex operations, such as multi-axis CNC machining, generally require a higher number of tools and greater tool wear, whereas simpler processes such as turning or vertical milling tend to use fewer tools. This variation highlights how the type of machining directly influences tooling requirements and overall production costs, reinforcing the need for accurate, real-time tracking to capture these differences.

The analysis also shows that the initial fixed percentage-based allocation of tooling costs — where, during the quoting process, a constant percentage of manufacturing cost was allocated to tooling based on best-guess practice — can often be inaccurate, either overestimating or underestimating the actual requirements for a job. With real-time data now available, managers can avoid overstating profitability when tooling needs are lower than estimated, while also preventing unexpected cost overruns when requirements are higher. This improved visibility supports more accurate quoting, strengthens procurement planning, and ensures that tooling strategies are aligned with the true demands of each machining process.

Furthermore, the Tooling Dashboard enables management to conduct weekly and monthly reviews of tooling costs at the manufacturing-order level. This allows the team to compare actual tooling expenses against expected benchmarks, identify cost-saving opportunities, and drive continuous-improvement initiatives. Identifying excessive tool usage on repeat jobs, now monitored using the same dashboard infrastructure, has led to process standardisation and tool-life optimisation. The system also creates the foundation for future integrations, such as predictive maintenance and closed-loop feedback based on machine performance and tool-wear analytics.

In terms of cultural impact, the transformation has fostered a stronger data-driven mindset across the organisation. Staff at all levels now value accurate, real-time data and have embraced digital practices more readily. The success of this tooling project has become a catalyst for broader digital initiatives within the company, including paperless job sheets, digital document viewers, and live machine-monitoring systems. The improved transparency has also strengthened cross-functional collaboration between shop floor operators and engineering staff.

III. Conclusion and Future Work

The digital transformation initiative at Bryken Ltd demonstrates how even SMEs can unlock substantial value through the strategic deployment of low-code and cloud-based technologies. By integrating real-time data, automating routine processes, and enhancing the visibility of critical operations, Bryken has not only improved its tooling efficiency but also elevated its overall operational maturity.

Looking ahead, Bryken plans to scale this tooling system further by incorporating IoT data for real-time tool-wear monitoring, implementing machine-learning models to predict tooling failures, and extending the digital platform to other consumables such as coolant and fixture components. There is also an ambition to link tooling data with quality metrics, enabling end-to-end traceability from raw material to final inspection.

Future work will also address reproducibility by publishing anonymised workflow schemas and SharePoint data models to support replication in similar SME contexts. Additionally, benchmarking against recent Industry 4.0 implementations in the literature [6][7] will strengthen the evidential basis of the reported improvements.

This case study illustrates that digital transformation does not require disproportionately high capital investment or complex proprietary systems. With thoughtful planning, a clear understanding of operational constraints, and strategic use of accessible technologies, manufacturers can position themselves for long-term resilience, agility, and competitiveness in an increasingly data-driven world. It is hoped that this example will encourage other SMEs in the precision engineering sector to embrace similar digital strategies and share their learnings with the wider manufacturing community.

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