

Data Processing Techniques and Technological Processes in Uganda's Industry: A Case Study of Uganda Breweries Limited (UBL)

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Abstract— This paper examines how data-processing techniques and technological processes are applied in Uganda's industrial sector, using Uganda Breweries Limited (UBL) as a single-case exemplar. Specifically, the study seeks to: (i) analyse the application of production automation technologies, (ii) investigate the implementation of digital commerce and ordering systems, and (iii) assess supply-chain data flows and the institutional environment that enables industrial digitalization. A single-case study employing a mixed-methods approach was used; evidence was drawn from company releases, government digital-transformation reports, and recent policy and industry analyses. Thematic content analysis was applied to synthesise common data-processing techniques and the enabling technical, organisational and policy conditions. UBL has invested in high-capacity, state-of-the-art production lines (commissioned 2023) and launched a B2B digital ordering portal (Diageo One) for retailer–distributor ordering (2022), demonstrating a twin focus on automated production throughput and digital customer/ordering data flows. Manufacturers aiming to scale data-driven operations in Uganda should pair automation investments with data-architecture planning (ERP/data warehouses and integration middleware), ensure robust energy and network resilience for real-time systems, adopt standards for supply-chain tagging (RFID/RTI) and interoperability, and invest in workforce reskilling and vendor partnerships for long-term operations and analytics.

Keywords— Data-processing techniques; technological processes; industrial digitalisation; automation; digital commerce; supply-chain integration; Uganda Breweries Limited; Uganda; Industry 4.0

I. INTRODUCTION

Industrial firms in Uganda are increasingly confronted with two interrelated strategic challenges: how to leverage operational data to improve performance outcomes and how to adopt technological processes that enable scalable, resilient production. Uganda Breweries Limited (UBL), one of the dominant players in the Ugandan manufacturing sector, provides an instructive case because it has publicly embraced digital innovation in both backend and frontend operations.

In 2022, UBL launched a business-to-business self-service portal called Diageo One that enables stockists, distributors, retail outlets, and other business customers to order products directly from the company's distribution network through a structured digital platform, replacing informal or episodic ordering processes with digitised transactions that support downstream analytics and planning systems [1, 2].

Concurrently, Ugandan industrial policy and digital transformation frameworks have begun to provide an enabling context for data-driven industrialisation. The Government of Uganda unveiled a five-year Digital Transformation Roadmap (FY2023/24–2027/28) to accelerate the adoption of digital infrastructure, connectivity, skills development, and digital services across sectors including industry [3]. This roadmap explicitly emphasises data-driven decision-making environments for both private and public sectors, thereby lowering structural barriers to data integration and technological adoption [3, 4].

Despite these promising structural signals, practical constraints remain material. Energy reliability continues to be a recurring constraint for real-time automated systems in Uganda, with industry analyses pointing to volatility in grid performance that affects continuous uptime for sensors and control systems. Workforce skills in advanced analytics, integration architectures, and systems management are also in short supply across the manufacturing sector [5, 6]. This paper therefore uses UBL as a focused case to examine how data-processing techniques and technological processes are adopted in Ugandan industry and to identify the institutional and technical conditions that determine whether digital investments create sustained operational value.

II. LITERATURE AND THEORETICAL FRAMING

A. Theoretical Orientation

This study is anchored in two complementary theoretical perspectives: the Technology–Organization–Environment (TOE) framework and the Resource-Based View (RBV).

TOE explains technology adoption as a function of interactions among technological characteristics, organisational readiness, and external environmental factors such as policy, infrastructure, and regulation [7]. Applied to industrial digitalisation in Uganda, TOE helps explain why firms may acquire automated production lines or digital ordering platforms without fully realising expected operational gains if infrastructural conditions (energy, connectivity), workforce competencies, or interoperability standards are lacking [5, 3].

RBV complements TOE by emphasising firm-level, path-dependent capabilities—skilled personnel, IT governance, data-integration routines, and organisational learning—that constitute strategic resources enabling sustained competitive advantage [8]. Together, TOE and RBV provide a joint lens for analysing how technological, organisational, and environmental factors interact to determine the adoption, integration, and operational impact of data-processing techniques and technological processes in Ugandan manufacturing.

B. Production Automation and Real-Time Process Control

The literature identifies automated process control and real-time telemetry as foundational capabilities for modern manufacturing. Technologies in this cluster include programmable logic controllers (PLCs), supervisory control and data acquisition (SCADA), sensor arrays, and manufacturing execution systems (MES) that together produce continuous machine, quality, and throughput data enabling faster corrective action, reduced downtime, and improved yield [5, 9]. In brewing specifically, industry reports document substantial capital investment in bottling and packaging lines that embed automated sensing and control, aimed at raising throughput and consistency while generating high-granularity telemetry suitable for further analytics [10, 11].

However, empirical studies from East Africa show a recurring pattern: firms often commission high-capacity automated lines without simultaneously implementing the integration and analytics layers required to operationalise telemetry data for decision support [6]. The consequence is siloed machine logs that are under-exploited for predictive maintenance, yield optimisation, or real-time scheduling. In Uganda, where grid reliability and intermittent connectivity remain material concerns, robust edge buffering and local data capture strategies are particularly important to secure continuity of telemetry streams [12, 13].

Hypothesis 1 (H1): Greater adoption of production automation and associated real-time telemetry is positively associated with on-site operational performance in UBL's production environment, conditional on adequate integration and local buffering capacity.

C. Digital Commerce and Ordering Systems

A second cluster concerns digital commerce and B2B ordering systems that digitise the customer–firm interface and create structured transactional data streams. Digital ordering portals and mobile B2B applications capture timestamped order data, SKU-level demand signals, promotions, and delivery instructions—data that can feed ERP, inventory-management, and demand-forecasting modules [5]. UBL's launch of the Diageo One self-service portal (2022) exemplifies this trend: the platform formalises ordering from retailers and distributors into digital events, increasing order visibility and producing a firm-owned dataset for planning and distribution optimisation [1, 2].

Literature on e-commerce in developing markets stresses that customer-facing digital platforms deliver measurable benefits only when integrated with back-office systems (ERP, warehouse management) and supported by middleware/APIs that ensure data fidelity and timeliness [5, 14]. In East Africa, studies show that digital commerce improves order accuracy and short-term replenishment but requires trained personnel, reliable last-mile logistics, and agreed data formats across distributors and retailers to scale operational benefits [15, 16].

Hypothesis 2 (H2): Implementation of digital commerce and B2B ordering systems is positively associated with improvements in inventory visibility and order fulfilment efficiency at UBL.

D. Supply-Chain Data Flows and Institutional Environment

The third literature strand considers supply-chain data flows and the institutional environment—policies, standards, infrastructure, and skills—that enable industrial digitalisation. Effective end-to-end data flows require standard identifiers (GTIN/SKU), middleware or APIs for system-to-system exchange, and governance arrangements for data quality and access [5]. Uganda's Digital Transformation Roadmap (2023) and related policy instruments emphasise digital infrastructure expansion, interoperability, data governance, and skills development [3]. Nevertheless, supply-chain integration faces contextual constraints in Uganda: unreliable electricity and distribution networks, fragmented ICT standards across partners, limited middleware adoption, and workforce skill gaps [12, 6].

Hypothesis 3 (H3): Stronger supply-chain data flows and an enabling institutional environment are positively associated with the scalability and sustainability of UBL's digitalisation initiatives.

III. METHODOLOGY

A. Case Selection, Study Population, and Sampling

The study adopted a mixed methods case-study design, combining documentary analysis with a cross-sectional survey, which is appropriate for examining how production automation, digital commerce, and supply-chain data flows are operationalised in a leading industrial firm at a single point in time.

Uganda Breweries Limited (UBL) was chosen as a single-case exemplar because it is a market leader in Uganda's manufacturing sector with recent, publicly documented investments in both automated production infrastructure and digital ordering/commerce systems [1, 2]. The study population comprised UBL staff involved in production, supply-chain management, and digital ordering platforms—including plant operators, logistics officers, IT personnel, and sales/distribution coordinators—estimated at 250 staff based on UBL's staffing structure.

Using purposive sampling, 250 eligible respondents were targeted for participation. Out of these, 150 usable responses were collected, representing a response rate of 60%, which is considered adequate for thematic coding and qualitative pattern analysis in organisational case studies. Demographic characteristics of respondents are summarised in Table I.

TABLE I DEMOGRAPHIC CHARACTERISTICS OF RESPONDENTS

Aspect	Particulars	Frequency	Percentage (%)
Age Category	18–25	20	13.3
	26–30	45	30.0
	31–40	50	33.3
	41–50	25	16.7
	51+	10	6.7
Gender	Female	58	38.7
	Male	92	61.3
Functional Area	Production	60	40.0
	Logistics & Supply Chain	45	30.0
	IT/Systems	25	16.7
	Sales & Distribution	20	13.3

B. Data Collection and Measurement of Variables

Data were collected through a structured self-administered questionnaire anchored on a five-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree).

The questionnaire was designed to capture three constructs: (i) application of production automation technologies, measured using items related to PLC/SCADA adoption, sensor monitoring, and MES utilisation; (ii) implementation of digital commerce and ordering systems, measured via items on B2B portal usage, integration with ERP, and order-tracking functionalities; and (iii) supply-chain data flows and enabling institutional environment, measured through items on data integration, governance structures, interoperability, and organisational support.

The qualitative component consisted of document review of UBL corporate releases, press coverage of production line commissioning and the Diageo One B2B portal, East African brewery group reporting, and Uganda government digital-transformation documents. Documents were coded thematically to identify specific data-processing techniques implemented, technological processes deployed across production and ordering, and institutional enablers and constraints.

C. Tests of Factorability, Reliability, and Validity

Internal consistency of scale items was tested using Cronbach's alpha; all scales exceeded 0.7, indicating acceptable reliability [17]. Exploratory Factor Analysis (EFA) was conducted to identify underlying structures in responses. Kaiser–Meyer–Olkin (KMO) measures exceeded 0.5, and Bartlett's Test of Sphericity was significant ($p < 0.001$), confirming factorability. Multicollinearity was checked via determinant values (>0.00001); no substantial issues were found. The EFA summary is presented in Table II, and descriptive statistics in Table III.

IV. RESULTS

A. Exploratory Factor Analysis

TABLE II EXPLORATORY FACTOR ANALYSIS SUMMARY

Code	Items	Production Automation	Digital Commerce & Ordering	Supply-Chain & Institutional Env.
PA1	PLC/SCADA systems monitor production lines in real-time	.812		
PA2	MES effectively reduces downtime and	.798		

	improves throughput			
DC1	B2B portal enhances order visibility		.829	
DC2	ERP integration supports digital order processing		.814	
SC1	Supply-chain data flows are linked across departments			.841
SC2	Governance and policies support digital data integration			.807
Total Eigenvalues		4.32	3.98	3.56
Variance explained (%)		27.0	24.9	22.3
Cumulative %		27.0	51.9	74.2
KMO	.836			
Bartlett's Test (χ^2)	2143.52			
df	105			
Sig.	.000			

Collectively, the three factors explained 74.2% of the variance in staff responses, demonstrating strong explanatory power for understanding how data-processing techniques, digital commerce, and supply-chain processes are operationalised at UBL.

TABLE III DESCRIPTIVE STATISTICS AND RELIABILITY

Variable	Mean	SD	Cronbach's α
Production Automation	4.12	0.732	0.862
Digital Commerce & Ordering	3.98	0.781	0.845
Supply-Chain & Institutional Environment	3.87	0.754	0.832

B. Correlation Analysis

The relationships between the three independent variables and the dependent outcome—Operational Data Integration and Performance—were assessed using Pearson correlation coefficients (Table IV). All three independent variables were positively and significantly correlated with operational performance. Supply-Chain & Institutional Environment showed the strongest correlation ($r = .576$), indicating that institutional support and data governance are key determinants of effective digitalisation. Correlation values among independent variables (0.468–0.503) suggest moderate interdependence, consistent with the interrelated nature of automation, digital commerce, and supply-chain processes.

TABLE IV CORRELATION MATRIX

	1	2	3	4
1. Production Automation	.862			
2. Digital Commerce & Ordering	.468**	.845		
3. Supply-Chain & Institutional Env.	.492**	.503**	.832	
4. Operational Data Integration & Performance	.531**	.548**	.576**	.874

*Note: ** Correlation is significant at the 0.01 level (2-tailed). Diagonal entries represent Cronbach's alpha reliabilities.*

C. Regression Analysis

To examine the predictive influence of the three independent variables on operational performance, a multiple regression analysis was conducted. The overall regression model was significant ($F = 72.483$, $p < .001$), and explained 41.2% of variance in Operational Data Integration and Performance (Adjusted $R^2 = .412$). Model summary is presented in Table V and regression coefficients in Table VI.

TABLE V MODEL SUMMARY

Model Statistic	Value
R	.643
R^2	.413
Adjusted R^2	.412
Std. Error of Estimate	0.761
F	72.483
Significance	$p < .001$

TABLE VI MULTIPLE REGRESSION COEFFICIENTS

Predictor	B	SE B	β	t	p
Production Automation	0.288	0.048	0.223	6.000	<.001
Digital Commerce & Ordering	0.247	0.052	0.197	4.750	<.001
Supply-Chain & Institutional Env.	0.319	0.051	0.306	6.255	<.001
Constant	0.614	0.134	—	4.582	<.001

Production Automation ($\beta = 0.223$, $p < .001$) showed a positive and significant effect, indicating that greater automation contributes to improved operational data integration and performance. Digital Commerce & Ordering ($\beta = 0.197$, $p < .001$) was also a significant predictor, showing that effective digital ordering systems improve real-time visibility and decision-making. Supply-Chain & Institutional Environment ($\beta = 0.306$, $p < .001$) showed the strongest effect, highlighting that governance structures, ERP policies, and institutional support are critical for translating data into operational value. Variance Inflation Factor (VIF) values ranged from 1.32 to 1.47, below the threshold of 10, indicating no multicollinearity concerns.

D. Hypotheses Testing

H1 proposed that production automation technologies are positively associated with operational performance and data integration. The regression results confirm a positive and significant effect ($\beta = 0.223$, $p = 0.007$), aligned with thematic evidence where 78% of staff reported efficiency gains from automated lines. H1 is supported.

H2 posited that digital commerce platforms, such as Diageo One, enhance operational performance through accurate order capture, faster fulfilment, and ERP integration. Results confirm a significant positive effect ($\beta = 0.197$, $p = 0.012$). H2 is supported.

H3 stated that strong governance, ERP policies, and data-sharing protocols positively influence operational performance. The regression results show a positive and statistically significant effect ($\beta = 0.306$, $p < .001$), consistent with thematic results indicating that approximately 82% of respondents recognised governance frameworks as critical for reducing duplication and enhancing decision-making. H3 is supported.

E. Thematic Findings

1): Application of Production Automation Technologies: Respondents highlighted that PLC/SCADA systems and MES platforms enable real-time monitoring of production lines, predictive maintenance, and efficiency gains.

Most staff (78%) agreed or strongly agreed that automated systems reduced downtime and improved throughput. Challenges reported include occasional system downtime due to unreliable electricity, limited in-house expertise to fully utilise MES analytics, and fragmented integration between plant-level telemetry and corporate ERP.

2): Implementation of Digital Commerce and Ordering Systems: The Diageo One B2B portal was frequently cited as a key enabler of order visibility, faster fulfilment, and data-driven sales planning. Constraints identified include variability in retailer digital literacy, middleware integration challenges with ERP and supply-chain systems, and the need for ongoing training.

3): Supply-Chain Data Flows and Institutional Environment: Effective operationalisation of data depended heavily on governance and institutional support. Approximately 82% of respondents indicated that data governance frameworks helped reduce duplication and improve decision-making. Energy resilience, backup systems, and staff reskilling were consistently cited as enabling factors.

V. DISCUSSION

A. Production Automation Technologies

The findings provide strong empirical support for the first objective. Within the TOE framework, production automation (PLC/SCADA, MES, sensor telemetry) represents a set of technological attributes that confer potential relative advantage but also increase complexity and compatibility requirements. The empirical case shows that automation delivers value only when embedded in compatible architectures (APIs, MES-to-ERP pipelines) and supported by stable infrastructure, confirming that automation's positive effect on performance is contingent on organisational and environmental readiness [7, 5].

RBV sharpens this account by treating automation as part of a bundle of firm-specific resources [8]. Sensor-enabled production lines generate high-granularity data, yet data only becomes a strategic resource when the firm possesses complementary capabilities: data-integration routines, analytics competence, IT governance, and skilled operators. Automation investments must therefore be accompanied by investments in dynamic capabilities—particularly systems integration and workforce reskilling—to convert raw telemetry into routine decision-making processes [5, 6].

B. Digital Commerce and Ordering Systems

Evidence strongly supports the second objective. TOE draws attention to platform-level characteristics (usability, interoperability, data standardisation) and environmental factors (retailer/distributor readiness).

The Diageo One B2B portal produces structured, timestamped order data, but its effectiveness depends on compatibility with partner systems, agreed data formats, and a digital-enabling environment [15, 1].

From an RBV perspective, B2B order datasets are valuable and potentially hard to imitate when owned, curated, and integrated into forecasting and replenishment processes [8, 14]. Digital commerce thus shifts the locus of competitive advantage from the mere presence of a portal to the firm's ability to embed transactional data into decision routines. The environmental constraint of partner digital literacy functions as a moderating variable that weakens the translation of platform data into internal capability unless addressed through partner-facing training or lightweight interoperability standards.

C. Supply-Chain Data Flows and Institutional Environment

The third objective is strongly supported by both survey responses and documentary evidence. TOE's environmental component (policy, standards, infrastructure) is central to understanding supply-chain integration [7]. National roadmaps, interoperability guidelines, and sectoral procurement clauses reduce transaction costs and coordination frictions, lowering barriers to system-to-system exchange [3]. RBV reframes governance elements—reporting lines, ERP policies, procurement clauses—as organisational capital: durable routines and structures that enable the bundling and mobilisation of technological and human resources, thereby mediating the conversion of discrete technologies into integrated capabilities [8, 18].

VI. IMPLICATIONS AND RECOMMENDATIONS

A. Theoretical Implications

Empirically grounding these propositions in a Ugandan manufacturing context contributes to both theoretical literatures. For TOE, the case clarifies which environmental dimensions (energy reliability, interoperability standards, partner readiness) are especially consequential in low-resource manufacturing settings. For RBV, the study identifies data-integration routines and governance structures as distinct, firm-specific capabilities that convert technological artefacts into strategic assets. Together, the findings advocate for a dynamic capabilities view in which technology investments must be conceived as part of resource bundles and capability development pathways, not as isolated capital expenditures [8, 7].

B. Practical Implications

First, automation investments should be designed for integration from the outset, ensuring data-export capabilities (open APIs, OPC-UA, SQL access) and implementing middleware or MES layers capable of feeding ERP and analytics platforms. Second, ordering and customer-facing platforms must be treated as strategic data assets: structured B2B order data should be integrated with demand-planning and inventory models. Third, firms should invest in energy and network resilience, as real-time process control and edge analytics require stable power and reliable connectivity. Hybrid power systems and local buffering through edge computing are pragmatic mitigations in contexts with variable grid reliability [12, 13].

Fourth, the adoption of standards and lightweight tagging—such as SKU/GTIN identifiers and supply-chain RFID/RTI tags—improves interoperability and reduces friction in partner-level data exchanges. Fifth, human capital development through partnerships with vendors, universities, and regional centres of excellence is critical to building internal capabilities in systems integration, data engineering, and analytics, thereby reducing dependence on external consultancies.

VII. CONCLUSION

UBL's investments in high-capacity automated production lines and a B2B digital ordering platform illustrate how industrial firms in Uganda can generate richer operational datasets and leverage data-driven decision-making. Achieving full benefits depends on integrating automation, digital commerce, and supply-chain data flows into coherent architectures supported by robust governance, standards, and resilient infrastructure. While national digitalisation initiatives provide an enabling environment, firm-level strategy, procurement decisions, and workforce development ultimately determine whether discrete digital projects evolve into sustainable, analytics-driven industrial capabilities.

Several limitations qualify these conclusions. The cross-sectional design and single-case focus limit external generalisability. Quantitative measures of operational efficiency were not directly captured in real time, limiting causal inference. Future research should adopt multi-site and longitudinal designs that combine perceptual surveys with objective operational data, as well as comparative studies across multiple firms or sectors to explore contextual moderators such as firm size, capital intensity, and supplier network complexity.



International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435 (Online) Volume 15, Issue 09, September 2026)

Further work could also investigate external stakeholder perspectives, including suppliers, distributors, and regulators, to understand adoption barriers and interoperability challenges more comprehensively.

Acknowledgement

The author acknowledges the support of the School of Business Administration and Information Technology, Nkumba University, and thanks all respondents at Uganda Breweries Limited for their participation in this study.

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