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Evaluating Foundry Utilization Constraints and Their Impact on Competitiveness

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Abstract

The foundry under study is a critical revenue-generating asset for one of the operating divisions of South Africa's largest railway company. However, its operational efficiency has deteriorated over time, leading to significant profit losses. The sustained decline in performance has resulted in a shortage of essential railway rolling stock components, posing risks to business continuity and potential job losses.This study aims to identify key constraints limiting the foundry's utilization relative to its installed capacity and to recommend targeted interventions to enhance efficiency, profitability, and competitiveness. A mixed-methods research approach, integrating both quantitative and qualitative analyses, was employed to assess operational bottlenecks. Findings indicate that external controls, internal controls, and support services are primary constraints, adversely impacting turnaround times and escalating operating costs.The study's insights contribute to existing research frameworks for diagnosing operational inefficiencies in manufacturing environments, particularly within state-owned enterprises. The validation of the theoretical model used in this research demonstrates its applicability and reliability in identifying and addressing production constraints in similar industrial settings.

Keywords
Foundry utilization, Capacity utilization, Operational constraints, Competitiveness, Capacity optimization, Theory of Constraints (TOC).

1. Introduction
In the contemporary business landscape, foundries play an important role in manufacturing high-quality metal components for a variety of industries, including automotive, aerospace, rail and construction. Over the years, extensive research has studied many aspects of foundry operations, from process optimization and resource allocation to technological adoption and environmental compliance. Studies by researchers such as McKie (2015) and Nyemba et al. (2017) highlight key challenges like equipment downtime, process inefficiencies, and resource underutilization as noteworthy barriers to optimal productivity. For instance, Nyakala et al. (2023) explored the constraints that limit productivity. Similarly, Phiri et al. (2024) focused on the impact of several macroeconomic factors on both foundry

production efficiency and the ability to expand into new markets. These studies have provided valuable insights into isolated constraints affecting foundry performance.

However, despite the depth of research on individual factors, there remains a notable gap in the literature: the lack of a holistic framework that integrates multiple utilization constraints and quantitatively assesses their collective impact on competitiveness. While studies have addressed issues such as lean manufacturing and process optimization separately, few have systematically examined how constraints like equipment limitations, workforce challenges, environmental mandates, and resource allocation interact to shape competitive performance in foundries. This fragmentation in the literature suggests that current models might not fully capture the complex interplay between these factors. Furthermore, existing research has tended to focus on internal process improvements without adequately linking these enhancements to broader market competitiveness. There is limited empirical evidence on how improvements in utilization directly translate into competitive advantages in terms of cost efficiency, market responsiveness, and innovation capacity. This gap is particularly critical in an increasingly competitive global market. South Africa is a part of this global market.

The South African foundry industry has faced notable challenges impacting its utilization rates. A benchmarking study highlighted that the country's foundries operate at an average capacity utilization of 43%, with the best-performing foundries reaching up to 75% (Mageza, Sedumedi & Pan 2023). In contrast, Chinese foundries operate at 90% capacity utilization, and European Union foundries at 54%. Factors contributing to South Africa's lower utilization include insufficient order, manual operations, and inadequate energy reliability (Mageza et al. 2023). This study aims to evaluate the key constraints affecting foundry utilization and analyze their impact on competitiveness. By identifying bottlenecks and inefficiencies, the research seeks to provide insights into how foundries can optimize their operations to enhance productivity and maintain a competitive edge. The current study seeks to develop an integrative framework that not only identifies the key constraints in foundry utilization but also evaluates their cumulative impact on overall competitiveness. By leveraging systems theory and performance measurement approaches, this research aims to provide a comprehensive analysis that bridges the divide between operational efficiency and competitive performance, offering both academic insights and practical recommendations for industry stakeholders.

1.1 Objectives

The objective of this study is to understand why Foundry X, a South African foundry, isn't fully utilized and to recommend effective solutions for overcoming the limitations.
To fulfil this objective the following research questions were answered:
What are the internal and external constraints that limit Foundry X from operating at its full installed capacity?
How do these constraints impact the foundry's operational performance, profitability, and competitiveness?
What intervention measures can be implemented to overcome these constraints?
How can the effectiveness of these interventions be evaluated over time?

2. Literature Review

This section provides an overview of the foundry industry capacity utilization, foundry operations, constraints on foundry utilization, competitiveness and how it is impacted by utilization constraints. OM intervention strategies, tools and best practices are reviewed. By understanding the foundry industry, utilization constraints, and how to identify them so as to intervene, foundry competitiveness can be improved

Foundry Operations Management and Competitiveness

Foundry operations employ general operations management principles used in manufacturing. Effective management is essential for optimizing production, minimizing waste, ensuring worker safety, and maintaining competitiveness in the industry. In particular, steel foundries play a key role in manufacturing high-strength castings for industries such as automotive, aerospace, construction, and heavy machinery. Managing steel foundry operations needs a strategic approach to ensure efficiency, quality, and cost-effectiveness while maintaining environmental and safety standards. Operations management procedures that are used in foundries to continuously improve costs, quality and efficiency of operations (Battistoni et al. 2013) include: World Class Manufacturing (WCM) approach; Total Quality Management (TQM) approach; Total Productive Maintenance (TPM) approach and Just-in-Time (JIT) or lean manufacturing (LM) approach.

In order for such practices to be effectively implemented and to assess performance, there is a need to have measures in place. Measures help to identify underperforming areas, hence constraints. Literature has identified these performance measurement parameters (Ferdows and De Meyer: 1990, Sarmiento et al. 2007):

Flexibility – diversity of products offered, resource planning, capacity, etc.
Dependability – reliability of production
Speed – production turnaround time
Quality – production performance
Cost – cost of production

A foundry that has high ratings in all these parameters stands a great chance of having a competitive advantage. Therefore, it is important to use them as a basis to identify and improve operation constraints in the operation environment to gain and/or sustain competitive advantage. According to Awwad et al. (2013), competitive advantage is the extent to which an organization can create and sustain a defensible position over its competitors. The competitive advantage is generally characterized by:

- Large market share
- High sales/demand
- Sustainable growth, and
- Brand preference/association

A sustainable competitive advantage directly contributes to long-term competitiveness.

Competitiveness is largely defined or driven by what markets value. Lin (2008) and Awwad et al. (2013) identified four key elements of competitiveness:

- Usage/relevance of the product offered
- Price of the product offered
- Delivery timelines of the product offered, and
- Quality of the product offered.

Other elements that may contribute to competitiveness due to their potential to attract markets include safety and innovation. Priorities of the competitiveness elements depend solely on the markets.

2.1 Foundry Capacity Utilization

Capacity is defined as the maximum output rate that can be produced by production line resources within a specific timeframe (Jadayil et al. 2017). This is determined by the constraint resource in the production line.

The classifications of capacity utilization rates include:

- Installed capacity utilisation rate – maximum output rate that can be achieved by the production line under ideal conditions – design/theoretical capacity
- Effective capacity utilisation rate – maximum output rate that can be sustained by the production line under normal operating conditions – accounting for downtime.
- Actual capacity - real output that is achieved over a given period, which includes both planned and unplanned downtime

The generic equation to determine the capacity utilisation rate is: (Reid and Sanders 2013: 336):

$$Capacity\ Utilisation\ Rate = \frac{Actual\ Output}{Design\ Capacity}\ X\ 100\%$$

The installed and effective capacity utilisation rates are determined based on this equation:

$$Capacity\ Utilisation\ Rate_{Installed} = \frac{Actual\ \ Output}{Installed\ Capacity}\ X\ 100\ \%$$

$$Capacity\ Utilisation\ Rate_{Effective} = \frac{Actual\ Output}{Effective\ Capacity}\ X\ 100\ \%$$

When the capacity utilization rate is significantly below 100% it indicates that production can be increased without additional investment on the production line. However, when the rate is closer 100%, then the production line runs a risk of not delivering required volumes on time should there be any disruptions, such as illness of personnel or breakdown in machinery, as there is limited flexibility in the production system.Foundry utilization refers to how effectively a foundry uses its resources, such as equipment, labour, and raw materials, to achieve optimal production levels. Effective foundry utilization is essential for achieving operational excellence, enhancing cost competitiveness, and sustaining long-term growth in a dynamic industrial environment. High utilization rates enable manufacturers to maximise the use of capital-intensive equipment, reduce per-unit costs and improve return on investment (ROI). The process of establishing the output rate that a production line can achieve within a specific timeframe refers to capacity planning. According to Varisco (2018), the capacity planning process is characterised by: Constraints within the product line

Core planning disciplines, namely:

- Manufacturing planning (MAN)
- Assembly planning (ASS)
- Logistic planning (LOG)
- Layout planning (LAY)

Associated planning functions.

Capacity planning is a strategic tool that synchronizes production capabilities with market demands, ensuring efficient operations and higher output rates

2.2 Constraints in the foundry industry

The foundry industry faces numerous challenges that limit production efficiency. These constraints can be categorized into technical, operational, and supply chain-related bottlenecks (Galage 2025). Operational constraints include capacity limitations and process inefficiencies while Technical Constraints include equipment and technology as well as technical skills. The supply chain constraints in the foundry industry comprise of raw material availability and quality, supplier reliability and lead times, logistics and transportation issues, inventory management as well as global sourcing and geopolitical risks

The operational constraints can also be classified as internal or external to the organisation. The internal constraints are the problems found within the organisation, while the external constraints are those outside the organisation that have influence over the functions of the organisation. Table 1 presents the internal and external operational constraints in an operations environment.

Table 1. The classifications of the operational constraints.

Internal Constraints	**External Constraints**
Internal controls	Markets
Production resources	Suppliers
Support services	Competitors
	External controls

By understanding and managing these constraints, foundries can optimize production, minimize costs, and sustain competitiveness in a dynamic market. Through addressing these challenges by implementing process improvements, technology adoption, and strategic investments, foundries can better position themselves for long-term success.

2.3 Intervention Strategies

Intervention strategies aim to address constraints across operations, technology, workforce, supply chain, and even environmental management. For process and capacity optimization such strategies include the Theory of Constraints (TOC), Root Cause Analysis and Continuous Improvement.

Theory of Constraints

TOC is a change method that operates on the fundamental belief that systems are only as strong as their weakest link. One single constraint can limit the performance of the entire system. Hence, it is important to identify and address bottlenecks effectively. TOC enables foundries to i) focus on the critical constraint, ii) put effort into the specific constraint and iii) define the necessary indexes that enable detection of the impact of the change made. This method is based on these fundamental rules: (Janosz 2028) .

- Identify the weakest link (constraint/ bottleneck) and evaluate the best activities to eliminate it. These steps are followed;
- Identify the Constraint – Recognizing the process, machine, or resource that limits production
- Exploit the Constraint – Making full use of the constraint without significant investments
- Subordinate Other Processes – Aligning all other processes to support the constraint
- Elevate the Constraint – Expanding the capacity of the constraint if required
- Repeat the Process – Identifying and addressing new constraints continuously
- Measure the impact of the implemented solution to elevate the constraint identified. The measurement parameters include:
    - Throughput (T) - money generated through sales.
      T = volumes sold x (unit selling price – unit variable costs)
    - Inventory (I) - money tied up in the system in the form of fixed and movable assets It is used to determine the Return on Investment (ROI) using the following equation:
      ROI = Net Profit/ Inventory
- Operational Expenses (OE)- money spent within the organisation to turn inventory into throughput

However, constraint identification and subsequent elimination strategy should be based on the markets analyses, supply and demand analyses, and competition analyses (Janosz, 2018).

2.4 Root Cause Analysis

There are three different root cause analysis tools: interrelationship diagram, cause-and-effect diagram, and current reality tree (Doggett, 2005). These tools provide a framework to evaluate the nature of the relationships between the operational constraints in the foundry environment. Of particular interest for this study is the interrelationship diagram. The interrelationship diagrams provide a visual representation that shows source causes of specific problems (operational constraints) and their mutual connections. The operational constraints may be considered both as causes and effects. Therefore, interrelationship diagrams allow the definition of cause-and-effect dependencies among the identified operational constraints.

2.5 Continuous Improvement

Continuous Improvement (CI) refers to the process improvements that are undertaken in stages, separated by a period of time. Evaluations are made at the end of each stage to determine whether improvements have, in fact, occurred. It, therefore, can be defined as a systematic effort to seek out and apply new ways of doing work, i.e., actively and repeatedly making process improvements. The basic steps involved in implementing a CI approach as suggested by Stockton and Lindley (1995) are:

- identify the problem to be resolved
- collect information about the problem and the alternative solutions
- identify an appropriate solution
- implement the solution
- monitor the changes that have taken place and ensure that improvements have occurred.

The key continuous improvement interventions include; Lean Manufacturing and Waste Reduction (*Value Stream Mapping, Kaizen Events, and 5S Methodology)* as well as Quality Management and Six Sigma *(Six Sigma tools, Statistical Process Control (SPC), and Root Cause Analysis)*. CI is essential for enhancing efficiency, quality, and competitiveness in the foundry industry. However, diversification strategies which aim to increase revenue by high sales volume of the products offered, may be used. Literature has identified two types of diversification strategies, namely: offensive and defensive (Gordon, 2022). An offensive diversification strategy is focused on taking market share from competitors. Defensive diversification is focused on diversifying to remain competitive because either the existing market segment has saturated and thus, the product offering has matured, or the market is lost to competitors.

To effectively mitigate operational constraints, enhance efficiency, and maintain a competitive edge in the market, foundries have to implement some intervention strategies and best practices.

3. Hypotheses

The research problem comprises two constructs made up of independent variables and dependent variables. The aim of this research is to assess Foundry X utilisation constraints and determine their impact on competitiveness. The independent variables for this study (i.e., potential constraints) include operations controls (strategy and policies, standards, KPIs, etc.); inputs to the production line (markets and suppliers); support services (finance, marketing, training, research and development, etc.); and production line resources (technologies, processes, workforce and product offering). The dependent variables are the utilisation and competitiveness of the foundry. The following hypotheses were made:

- **H1**: The clients or markets affect utilisation and competitiveness of Foundry X.
- **H2**: The suppliers affect utilisation and competitiveness of Foundry X.
- **H3**: The diversification of product offerings affects utilisation and competitiveness of Foundry X.
- **H4**: The production processes and decision-making affect utilisation and competitiveness of Foundry X.
- **H5**: The management of manufacturing technologies affects utilisation and competitiveness of Foundry X.
- **H6**: The internal and external control affect utilisation and competitiveness of Foundry X.
- **H7**: The support services affect utilisation and competitiveness of Foundry X.

4. Methods

A single case study approach using both quantitative and qualitative methods was taken. The case study foundry is referred to as Foundry X. The target population was 92 stakeholders in the operations of Foundry X. The population categories comprised of Clients, Suppliers, Governance, Production, and Support Services. Non-probability purposive sampling was used. The research focused on 36 respondents. Primary data was gathered using online questionnaires and semi-structured face-to-face interviews. Secondary data sources included the company website and available documents**.** Microsoft Excel was used to statistically analyse the quantitative data acquired using a Likert scale. Factor analysis was used for the qualitative data.

5. Data Collection

Interviews were conducted using both physical methods (face-to-face) and digital methods (Microsoft Teams). The digital method helped to reach out to respondents from wherever they were located during the data collection period of this study. To protect the identities of respondents or to ensure their anonymity, each participant interviewed was assigned a code. Qualtrics platform was used to conduct online surveys. The first page of the survey is a cover letter which outlines the background of the research and its objectives to the respondents. The second page obtains the demographic information of the respondents. The survey questions start from the third page until the last page. The Likert scale was used to rate all the statements in the questionnaire.
A reliability test on the data obtained is conducted using the Cronbach's alpha equation (Kaban 2021).

6. Results and Discussion

The analysis performed involves descriptive statistics, qualitative analysis, and correlation analysis

6.1 Secondary Data Analysis

Foundry X's resources are focused on the production line resources, which include workforce, processes and technologies. Table 2 illustrates the breakdown of the Foundry's resource utilisation data. It shows that the installed production facilities at the foundry are largely under-utilised while the available facilities are over-utilised including the workforce. The capacity needed to meet current demand exceeds what is available. Hence, the foundry is insufficiently staffed to meet current demands.

Table 2. The analysis of Foundry X resources.

	Required capacity	**Installed capacity**	**Available capacity**	**Used capacity (average)**	**Utilisation rate (installed)**	**Utilisation rate (available)**
Creating mould	200 moulds/day	50-80 moulds/day	50-80 moulds/day	14-30 moulds/day	28-37%	28-37%
Melting and pouring molten steel into the mould	22 tons/ day	18 tons/day	9 tons/ day	9 tons/ day	50%	100%
Cooling process	24hrs	24hrs	24hrs	24hrs	100%	100%
Shot blasting	3 machines	3 machines	1 machine	1 machine	33.33%	100%
Grinding and polishing	4 grinders	2 grinders	2 grinders	2 grinders	100%	100%
Heat treatment	4 air quenches	2 air quenches	2 air quenches	1 air quench	50%	50%
Testing	1 on-site lab	1 on-site lab	1 on-site lab	1 on-site lab	100%	100%
Inventory (finished products)	Need new warehouse	None	None	None	N/A	N/A
Workforce	120	56	38	38	67.9%	100%

6.2 Primary Data Analysis

Online Survey

The independent variables of the study were; clients, suppliers, external controls, internal controls, production processes and decision-making, product offerings, technologies or production facilities, and support services. The performances of these variables were evaluated using the foundry performance measurement parameters by providing the respondents with a series of statements and requesting them to rate them using the 5-point Likert scale. The reliability test of the obtained data was conducted using Cronbach's alpha equation. The categories of the respondents are presented in Figure 1 while Table 3 shows the mean values obtained for descriptive statistics of the independent variables.

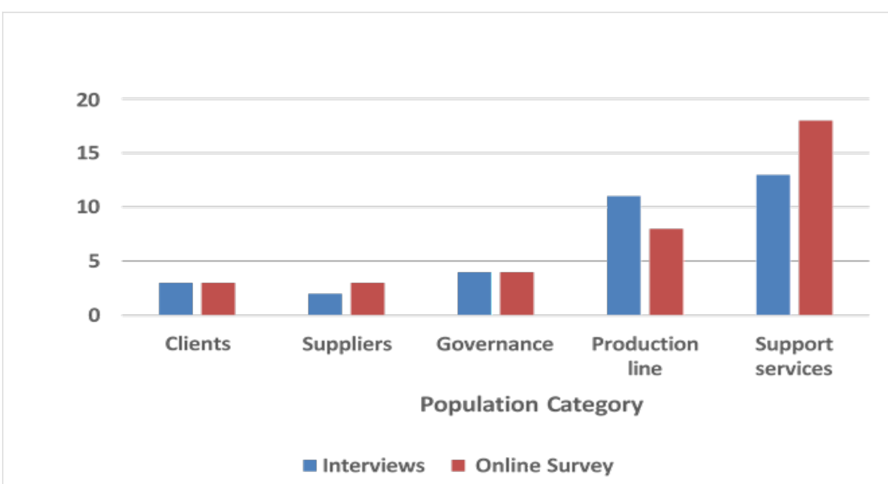

Figure 1. Categories of respondents

Table 3. The mean values of the descriptive statistics of the independent variables across performance dimensions.

Independent Variables	**Dependability**	**Quality**	**Flexibility**	**Cost**	**Speed**
Clients	**3.83**	3.50	3.64	3.31	3.25
Suppliers	3.83	3.78	**4.06**	2.86	3.47
External Control	3.22	3.50	3.25	**2.86**	**2.86**
Internal Control	3.59	3.65	3.21	3.37	3.19
Product Offering	3.53	3.47	3.61	3.11	3.14
Production Process & Decision Making	3.66	3.78	3.60	3.34	3.32
Technologies	3.49	3.54	3.31	3.04	3.19
Support Services	3.30	3.36	3.27	3.27	3.22

Reliability tests that were conducted produced a Cronbach alpha of greater than 0.7 for all the variables
On clients, respondents generally agree on the foundry's Dependability, Quality and Flexibility. However, their view is that there might be a slight lag in responsiveness or quick service delivery.
Respondents have a stronger agreement on the foundry's Flexibility, Dependability and Quality when dealing with suppliers. There is a general concern about Cost even though overall performance on other dimensions is positive.
With regard to external control, respondents generally somewhat disagree on Cost and Speed, suggesting that external control factors may be less effective or consistent compared to other areas.
Overall, The respondents somewhat disagreed that the Suppliers and External Controls variables promote cost-effective operations in the foundry.
The respondents somewhat disagreed that the External Controls variable promotes speed or efficiency of operations in the foundry.
The respondents were unsure whether current technologies used in the foundry support cost-effective operations.
The respondents are also unsure whether current products offered by the foundry were sold at competitive prices.
The respondents agree and/or strongly agree that all the variables support the dependability, quality and flexibility of operations in the foundry.

6.3 a. Correlation Analysis

The correlation table shows how each pair of variables related to foundry operations management is linearly associated (Table 4). The Pearson correlation coefficients range from 0.13 to 0.99, indicating varying degrees of association—from weak to extremely strong—among the variables

Table 4. The correlation analysis of the variables.

	Clients	***Suppliers***	***External Control***	***Internal Control***	***Product Offering***	***Production Process and Decision Making***	***Technologies***	***Support Services***
Clients	1							
Suppliers	0.71	1						
External Control	0.63	0.74	1					
Internal Control	0.46	0.13	0.65	1				
Product Offering	0.87	**0.90**	0.83	0.33	1			
Production Process and Decision Making	0.73	0.73	**0.99**	0.72	0.85	1		
Technologies	0.71	0.78	0.91	0.71	0.78	0.94	1	
Support Services	0.42	0.33	0.88	0.87	0.54	0.88	0.77	1

Table 4 shows:The External controls variable has the strongest relationships with all variables. This implies that a change in the External controls variable will affect all other variables.

The Internal controls variable has moderate to strong relationships with all variables that are within the foundry. So, a change in the Internal controls variable will affect all internal variables (i.e. product offering, production processes and decision-making, and production technologies or facilities).The Support services variable has moderate to strong relationships with internal foundry production variables (i.e., production processes and decision-making, and production technologies or facilities). Therefore, a change in the Support services variable will affect the operations of the foundry production variables.

6.3.b. Variables Interrelationships

In establishing the nature of the relationships between the variables or potential Foundry X utilisation constraints, the respondents were asked to respond to descriptive questions whether they agree, disagree or not sure (i.e., neither agree nor disagree) if the respective variables have control on each other. This exercise was done during semi- structured interviews. Only 'agree' responses were recorded in the interrelationship matrix to establish relatedness of the variables. Table 5 below illustrates the completed interrelationship matrix based on responses obtained from the respondents

Table 5. The variables' interrelationship matrix

CAUSES	**EFFECTS**							
	Externa l controls	Internal controls	Support Service s	Clients	Suppliers	Product Offerin g	Production processes and decision making	Technologies
External controls		**33**	**33**	**33**	**33**	**33**	**33**	**33**
Internal controls			**33**	**33**	**33**	**33**	**33**	**33**
Support Services				**33**	**33**	**33**	**33**	**33**
Clients						**33**	**33**	**32**
Suppliers						**33**	**33**	**33**
Product Offering			**33**	**33**	**33**		**33**	**33**
Production processes and decision making				**33**	**31**	**33**		**33**
Technologies				**32**	**33**	**33**	**33**	

Figure 2 shows the variables' interrelationship diagram. It shows that the External controls variable is the main source because it has the highest number of out-arrows. Next, are the Internal controls and Support services variables, respectively. The other variables are classified as effects because their in-arrows outweigh their out-arrows. Therefore, they are not constraints in the operations of the foundry but rather effects.

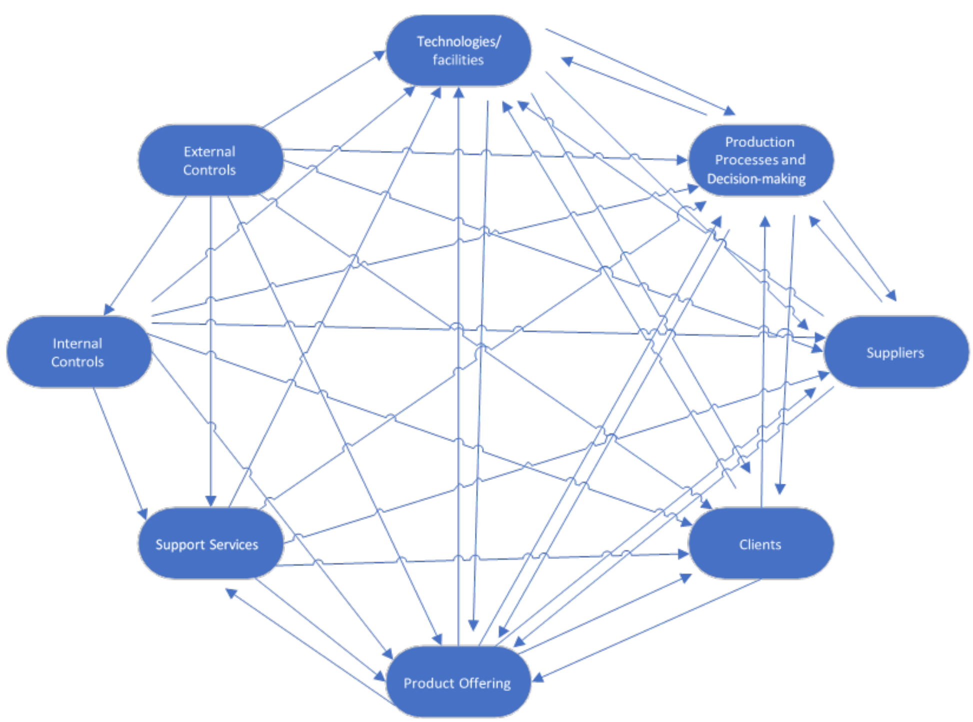

Figure 2. The variables' interrelationship diagram

6.4. Hypothesis Testing and Analyses

H1: The clients influence the utilisation and competitiveness of Foundry X.
From the Correlation Analysis results, there are strong relationships between the Clients variable and Product Offering, Production Processes and Decision-making, and Technologies variables. Therefore, this hypothesis is valid. However, from the Interrelationship results, the Clients variable was found to be an effect, and therefore, it is not the constraint on the utilisation and competitiveness of the foundry.

H2: The suppliers influence the utilisation and competitiveness of Foundry X.
From the Correlation Analysis results, there are strong relationships between Suppliers variable and Product Offering, Production Processes and Decision-making, and Technologies variables. Therefore, this hypothesis is valid. However, from the interrelationship results, the Suppliers variable was found to be the effect and therefore, it is not the constraint on the utilisation and competitiveness of the foundry.

H3: The diversification of product offering influences utilisation and competitiveness of Foundry X.
From the Correlation Analysis results, there are strong relationships between Product offering variable and Production processes and decision-making, and Technologies variables. Therefore, this hypothesis is valid. However, from interrelationship results, the Product offering variable was found to be the effect and therefore, it is not a constraint on the utilisation and competitiveness of the foundry.

H4: The production processes and decision-making affect the utilisation and competitiveness of Foundry X.
From the Correlation Analysis results, there are strong relationships between the Production processes and decision-making variables and Product offering and Technologies variables. Therefore, this hypothesis is valid. However, from the interrelationship results, the Production processes and decision-making variable were found to be the effect. Therefore, it is not a constraint on the utilisation and competitiveness of the foundry.

H5: The management of manufacturing technologies affects the utilisation and competitiveness of Foundry X.
From the Correlation Analysis results, there are strong relationships between the Technologies variable and Production processes and decision-making, and Product offering variables. Therefore, this hypothesis is valid. However, from the interrelationship results, the Technologies variable was found to be the effect in this study and therefore, it is not the constraint on the utilisation and competitiveness of the foundry.

H6: The internal and external controls affect the utilisation and competitiveness of Foundry X.
From the Correlation Analysis results, there are strong relationships between the External controls and Production processes and decision-making, Product offering and Technologies variables. Also, the Internal controls variable has moderate to strong relationships with these variables. Therefore, this hypothesis is valid. From the interrelationship table, both External and Internal controls variables were found to be causes. Therefore, this means that these variables are the constraints on the utilisation and competitiveness of the foundry, with the External control variable being the main constraint.

H7: The support services affect the utilisation and competitiveness of Foundry X.
From the Correlation Analysis results, there are moderate to strong relationships between the Support services variable and Production processes and decision-making, Product offering and Technologies variables. Therefore, this hypothesis is valid. From the interrelationship results, the Support services variable was found to be the constraint on the utilisation and competitiveness of the foundry. It follows the Internal controls variable.

7. Conclusion and Recommendations

The variables External controls, Internal controls, and Support services were identified as constraints that limit the utilisation of Foundry X to its installed capacity. The External controls variable was identified as the main constraint in terms of operating costs and speed, followed respectively by the Internal controls and Support services variables both in terms of operational speed. This suggests that the identified constraints collectively impact the competitiveness of the foundry negatively in terms of speed and cost. According to respondents, this is mainly due to:

- Long procurement processes that must be followed when acquiring goods and services,

- Challenges of not being able to directly do business with OEMs on many occasions as most of them do not meet some of the requirements stipulated in the – Public Finance Management Act South African government (PFMA)
- Absence of investment in recruiting the workforce required to meet the demands, and
- Lack of investment in advanced technologies that can improve production costs and efficiencies in Foundry X.

So, in addressing these constraints using the TOC approach, the resources should be focused on elevating the External controls constraint, specifically on adopting policies that will improve operating speed and costs in the foundry. Upon elevating the External controls constraint, the focus should then be on the Internal controls followed by the Support services, if the constraints do not move as they tend to do. The performance of the interventions made should be measured using the TOC measurement parameters, thus, throughput, inventory and operating expenses.Future research should be broadened to get diverse inputs or views from government employees, especially PFMA policy champions; and former suppliers, external clients and employees who were involved in the operations of the foundry. This will help to improve accuracy of results and participation rate as well.

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Biographies

Hilda Kundai Chikwanda

Professor Hilda Kundai Chikwanda is a distinguished Professor of Engineering Technology Management with over 30 years of experience in metallurgical engineering and operations management. Complemented by an MBA, her expertise spans both the technical and business aspects of the field. Professor Chikwanda has dedicated her career to advancing production efficiencies and fostering innovative practices in academic and industrial settings. She earned her PhD in Engineering and her MBA from leading institutions, equipping her with a unique blend of technical insight and managerial acumen. This dual expertise enables her to seamlessly bridge cutting-edge research with real-world applications, preparing her students to navigate the complexities of modern engineering challenges.

A passionate educator and mentor, Professor Chikwanda is committed to inspiring the next generation of engineers and managers. She emphasizes the critical importance of continuous improvement and innovation as drivers of industrial success. Her extensive publication record further underscores her influence and contribution to the fields of metallurgical engineering and operations management.

Biography Clifford Mabotha

Clifford Mabotha is a Principal Engineer specializing in tdesign, development and maintenance of SCADA systems for Rail and Port applications. He has over eight years of experience in solving complex engineering problems in Rail and Ports industries, including technical support services. Well-versed in LABVIEW and SIMATIC STEP 7 and WinCC programming languages to develop HMIs and back-end software. Clifford is able to work with various communication protocols (Modbus, CANopen, RS485, RS232 and Ethernet). He is a Professional Engineer with a master's degree in Engineering management.