



Assessing Technological Capability Gaps at an Ethiopian Metal-Manufacturing Plant: Implications for Industrial Upgrading

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Abstract

Research on Ethiopian manufacturing has largely focused on productivity and capital deepening, while enterprise-level technological capability development remains underexamined. This study assesses plant-level technological capability and capability gaps at Mesfin Industrial Engineering PLC-Gelan Manufacturing Plant, Ethiopia. An explanatory mixed-methods case-study design was employed. Quantitative data were obtained through a census of 72 employees in production, maintenance, and quality, using a 24-item instrument adapted from Arnold and Thuriaux's (1997) nine-dimensional technological-capability framework. The data were analyzed using proportional weighted scores and descriptive statistics. Qualitative evidence was generated through interviews with five key informants, observation, and document review, and was analyzed thematically to explain the quantitative results. The overall capability score was 54.86%, indicating low capability. Implementation Capability was the only moderate dimension (62.85%), while Assessment and Selection Capability was the weakest (51.91%). A 15-item assessment of capabilities for acquiring, absorbing, adapting, and improving transferred technologies produced a low score of 54.63%. Qualitative Findings also revealed reactive technology planning, aging equipment, limited modernization, inadequate training and knowledge documentation, weak organizational learning, and insufficient external collaboration. The study concludes that upgrading requires integrated interventions in technology planning, assessment and selection, knowledge transfer, employee development, equipment modernization, external partnerships, and continuous improvement. Theoretically, it provides empirical evidence of the framework's applicability in a late-industrializing African manufacturing enterprise. Practically, it proposes a prioritized pathway focusing first

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on Assessment and Selection Capability, Technology Awareness, and External Linkages, while strengthening learning and implementation.

Subject Areas

Industrial Engineering

Keywords

Technological Capability, Capability Gaps, Metal Manufacturing, Technology Upgrading, Organizational Learning, Industrial Competitiveness, Ethiopia

1. Introduction

Technological capability refers to an enterprise's ability to identify, acquire, operate, maintain, adapt, and improve technology through technical knowledge, employee skills, managerial practices, organizational routines, and learning processes [1] [2]. In developing economies, acquiring imported equipment or production technology does not automatically lead to higher productivity or competitiveness. Firms must also develop the capabilities required to assess, assimilate, implement, adapt, and improve acquired technologies through training, maintenance, problem-solving, knowledge sharing, learning-by-doing, and continuous improvement [3] [4]. Therefore, technological capability concerns not only the possession of machinery but also the organizational ability to transform technology into improved production, quality, innovation, and competitiveness [5] [6].

Manufacturing is central to Ethiopia's industrialization and structural-transformation agenda. However, Ethiopian manufacturing enterprises continue to face challenges related to productivity, technical efficiency, employee skills, capital modernization, technology adoption, and innovation [7] [8]. Existing firm-level studies have mainly focused on productivity growth, capital deepening, technology adoption, and innovation performance [7] [8]. Although these studies provide important evidence on firm outcomes, they offer limited explanation of the internal organizational mechanisms through which firms develop and use technological capability. In particular, technology awareness, technology search, assessment and selection, acquisition, implementation, organizational learning, knowledge sharing, and external knowledge integration remain insufficiently examined. Consequently, technological inputs and performance outcomes are often observed without adequately explaining the capability-building processes linking them. Technology adoption and industrial upgrading are therefore frequently treated as a "black box".

Collectively, these limitations indicate that the organizational and learning processes underlying technological-capability development in least-developed-country manufacturing firms remain insufficiently understood.

Three related research gaps can be identified. First, at the regional level, micro-level empirical evidence on technological-capability development in African and Ethiopian manufacturing enterprises remains limited. Existing research has con-

centrated more on productivity, innovation, technology adoption, and physical-capital investment than on the internal routines, skills, organizational practices, and learning processes that enable firms to use, adapt, and improve technology.

Second, at the theoretical level, the applicability and limitations of the nine-dimensional Technological Capability Assessment Framework developed by Arnold and Thuriaux (1997) remain insufficiently examined in least-developed-country manufacturing contexts [9]. Although the framework includes technology awareness, technology search, core competence, technology strategy, assessment and selection, acquisition, implementation, learning, and external linkages, it remains unclear whether these dimensions fully capture constraints associated with imported-technology dependence, limited technical skills, aging equipment, weak research linkages, financial limitations, and underdeveloped local supplier networks.

Third, at the industry level, the characteristics and causes of technological-capability gaps in metal-manufacturing enterprises remain underexplored. Metal manufacturing is strategically important because it supplies machinery, fabricated metal products, engineering services, and production inputs to sectors such as construction, agriculture, energy, transportation, and manufacturing. Nevertheless, limited research has examined how equipment conditions, engineering skills, maintenance systems, technology-selection practices, organizational learning, and external technical relationships influence capability development in this sector.

This study addresses these gaps by examining Mesfin Industrial Engineering PLC-Gelan Manufacturing Plant (MIE), an Ethiopian metal-manufacturing enterprise engaged in machinery production, electromechanical work, metal fabrication, and engineering services. Founded in 1993, MIE is an established engineering and metal-manufacturing enterprise serving sectors including transportation, energy, construction, and agriculture. Its long operational history, diversified manufacturing activities, and accumulated production and technological experience make it a suitable case for examining technological-capability development in Ethiopia's metal-manufacturing sector. Although the findings are not statistically generalizable to all manufacturing firms, the case provides analytical insights relevant to enterprises operating under imported-technology dependence, resource constraints, limited technical skills, and ongoing industrial upgrading.

The study applies the nine-dimensional Technological Capability Assessment Framework adapted from Arnold and Thuriaux (1997) [9]. The Resource-Based View identifies the plant's internal technical resources and capabilities, while Dynamic Capability Theory explains how these resources and routines are coordinated, adapted, and reconfigured during technology implementation and learning [5] [6].

The study addresses the following questions:

- 1) What is the aggregated employee-assessed level of technological capability at MIE-Gelan Manufacturing Plant?
- 2) What are the major strengths and gaps across the nine dimensions?

3) What is the level of capability in technology assessment and selection, acquisition, implementation, organizational learning, and external linkages?

4) What strategic interventions could strengthen technological capability and support industrial upgrading and competitiveness?

The study contributes micro-level evidence to the limited literature on technological capability in African manufacturing, examines the applicability of the Arnold and Thuriaux framework in a least-developed-country context, and provides industry-specific evidence on technological constraints in metal manufacturing. Practically, it identifies priority capability areas and proposes a phased upgrading pathway focusing on technology strategy, assessment and selection, acquisition, organizational learning, external linkages, and continuous improvement.

2. Literature Review

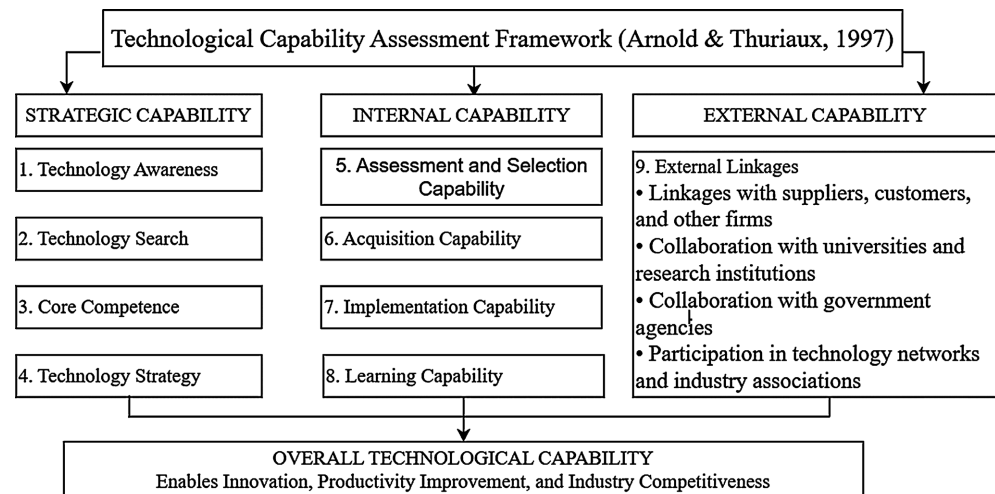
2.1. Technological Capability

Technological capability refers to an enterprise's ability to identify, acquire, operate, assimilate, adapt, and improve technology in response to production requirements. It extends beyond ownership of machinery and equipment to include technical knowledge, employee skills, managerial practices, organizational routines, and learning processes required for effective technology use [1] [9]. Technology transfer primarily concerns the movement of equipment, knowledge, or technical assistance from external sources, whereas technological capability concerns the recipient enterprise's ability to use, internalize, modify, and improve the transferred technology [1] [2].

Technology acquisition alone does not guarantee improved manufacturing performance, particularly in developing economies. Enterprises also require absorptive capacity, understood as the ability to recognize the value of external knowledge, assimilate it, and apply it to productive activities [3]. In this study, absorptive capacity is treated as a related theoretical concept rather than as a separately validated measurement scale. Technological capability develops through practical experience, employee training, technical problem-solving, knowledge sharing, maintenance, learning-by-doing, learning-by-using, and adaptation to enterprise-specific production conditions [1] [9]. Although related to innovation capability, technological capability is broader because it includes the ability to identify, assess, select, acquire, implement, operate, learn from, adapt, and improve technology [9].

2.2. Technological Capability Dimensions and Assessment Framework

This study applies the Technological Capability Assessment Framework developed by Arnold and Thuriaux (1997) [9]. **Figure 1** presents the technological capability assessment framework used in this study. The framework organizes technological capability into three interrelated domains: strategic capability, internal capability, and external capability.



Note. Adapted from Arnold and Thuriaux (1997) [9].

Figure 1. Technological capability assessment framework.

Strategic capability includes technology awareness, technology search, core competence, and technology strategy. These dimensions concern the enterprise's capacity to recognize technological needs and opportunities, search for relevant technologies, identify internal technical strengths, and align technology decisions with organizational objectives. Internal capability comprises assessment and selection, acquisition, implementation, and learning capabilities. Together, these dimensions reflect how technology is evaluated, obtained, implemented, operated, and incorporated into organizational routines. External capability is represented by linkages with suppliers, customers, other enterprises, universities, research institutions, government agencies, technology networks, and industry associations [9].

The nine dimensions provide a structured basis for assessing technological-capability strengths and gaps. They are used in this study as analytical dimensions for assessing MIE-Gelan's capability profile; they are not treated as independently validated causal variables.

2.3. Theoretical Foundations

Three complementary perspectives inform the study. The Resource-Based View explains how technical knowledge, employee skills, organizational routines, and other internal resources may function as strategic capabilities [10]. Dynamic Capability Theory emphasizes the ability to sense technological opportunities, seize them through appropriate decisions, and reconfigure resources as technological and production conditions change [11]. Organizational Learning Theory explains how knowledge is acquired, shared, retained, and converted into improved routines and problem-solving capacity [12] [13].

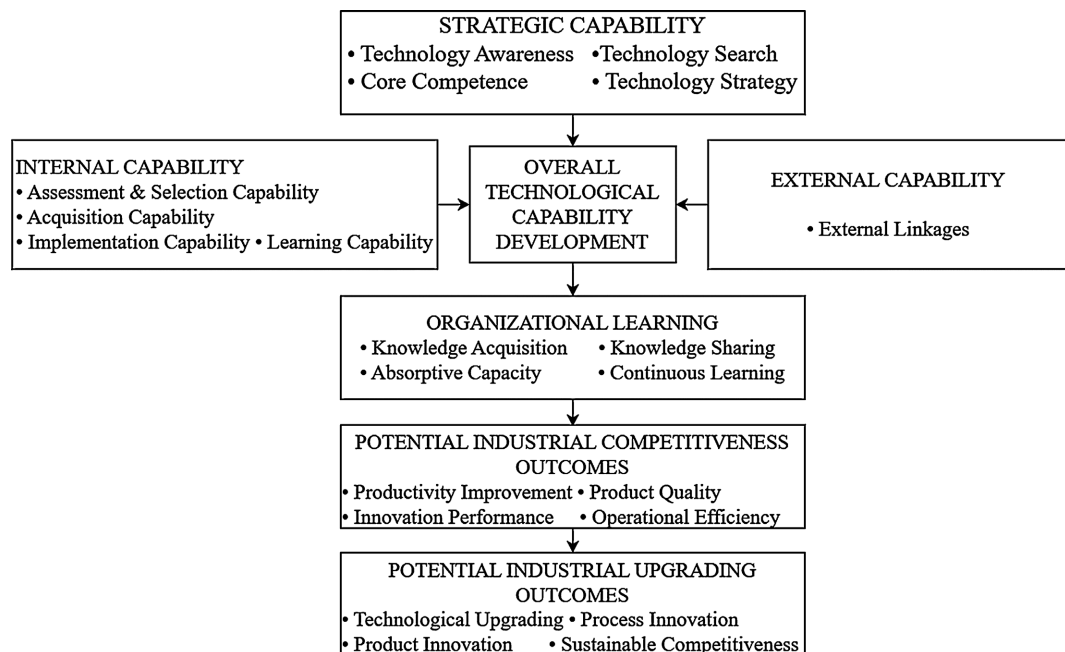
These theories serve as interpretive lenses rather than variables tested through causal analysis. The Resource-Based View is particularly relevant to core competence, implementation, and learning; Dynamic Capability Theory relates to technology awareness, search, strategy, assessment, acquisition, and adaptation; and

Organizational Learning Theory informs the interpretation of knowledge sharing, learning-by-doing, absorptive processes, and continuous improvement [10]-[14].

2.4. Integrated Conceptual Framework of the Study

Figure 2 integrates the nine technological-capability dimensions with the three theoretical perspectives [14]. Strategic, internal, and external capabilities are treated as interconnected components that contribute to overall technological capability development [15] [16]. The framework further presents organizational learning, including knowledge acquisition, knowledge sharing, absorptive processes, and continuous learning, as a mechanism through which technological capability may be developed and strengthened [17] [18].

The framework identifies potential links between technological capability, organizational learning, and broader outcomes such as productivity improvement, product quality, innovation performance, operational efficiency, technological upgrading, process innovation, product innovation, and sustainable competitiveness [17]-[19]. Because these outcomes were not directly measured in this study, they are presented as potential implications rather than demonstrated causal effects. The framework therefore guides the assessment and interpretation of MIE-Gelan's technological-capability profile without claiming to statistically test the proposed relationships.



Note. Developed by the author based on Arnold and Thuriaux (1997) [9], the resource-based view, dynamic capability theory, and organizational learning theory.

Figure 2. Integrated conceptual framework of the study.

2.5. Literature Review Summary

The reviewed literature demonstrates broad agreement that technological capa-

bility is a critical determinant of manufacturing performance, innovation, productivity improvement, and long-term competitiveness [1] [2] [15]. Existing studies consistently emphasize that technological capability extends beyond the acquisition of machinery and equipment to include organizational routines, employee skills, knowledge management, learning processes, technology strategy, and external knowledge linkages [1] [3].

The Resource-Based View, Dynamic Capability Theory, and Organizational Learning Theory further suggest that sustainable technological development depends on the effective integration of internal resources, adaptive organizational processes, and continuous learning [10]-[12].

Despite this consensus, several limitations remain in the existing literature. First, empirical evidence on technological capability development in African manufacturing enterprises remains limited, particularly at the firm level. Most studies focus on productivity, innovation outcomes, technology adoption, or investment performance, while providing limited insight into the internal capability-building mechanisms that support technological development [7] [8]. Second, although the Technological Capability Assessment Framework of Arnold and Thuriaux (1997) has been widely recognized as a comprehensive framework for assessing enterprise-level technological capability, its applicability within least-developed-country manufacturing environments remains insufficiently examined [9]. Third, limited research has specifically investigated technological capability gaps within metal-manufacturing enterprises, despite their strategic importance for industrial development and industrial upgrading.

These limitations indicate the need for firm-level empirical studies capable of examining technological capability as a multidimensional organizational phenomenon rather than as a simple outcome of technology acquisition. In response to these gaps, the present study applies the Arnold and Thuriaux (1997) framework to assess technological capability at Mesfin Industrial Engineering PLC-Gelan Manufacturing Plant. The study focuses on nine technological-capability dimensions and examines their strengths, weaknesses, and implications for future industrial upgrading.

Accordingly, the conceptual framework presented in **Figure 2** serves as the analytical foundation of this study. It links strategic capability, internal capability, external capability, and organizational learning to overall technological capability development and provides the basis for the research design, data collection, analysis, and interpretation of the technological capability profile of MIE-Gelan Manufacturing Plant.

3. Research Methodology

3.1. Research Design

This study employed a mixed-methods case-study design to assess the technological capability of Mesfin Industrial Engineering PLC-Gelan Manufacturing Plant (MIE-Gelan) in Ethiopia.

MIE-Gelan was purposively selected as the case-study site. Mesfin Industrial Engineering, established in 1993, is one of Ethiopia's leading metal-construction and electromechanical-engineering enterprises, serving the energy, mining, construction, transportation, and agricultural sectors [20] [21]. As an established manufacturing facility integrating fabrication, machining, maintenance, engineering, and quality-management functions, MIE-Gelan operates within a technologically intensive production environment. The plant was selected because it provides a suitable setting for examining how technological capabilities are acquired, applied, and developed in manufacturing operations. Furthermore, the case reflects many of the technological-learning, resource, skills, and industrial-upgrading challenges faced by manufacturing firms in developing economies. Although the study focuses on a single manufacturing plant, the findings are intended for analytical rather than statistical generalization and may provide insights relevant to similar manufacturing enterprises operating under comparable conditions [22].

Quantitative data were collected using a structured questionnaire to measure technological capability levels across the nine dimensions of the Technological Capability Assessment Framework developed by Arnold and Thuriaux (1997). Qualitative data were collected through semi-structured interviews, direct observation, and document review to explain the organizational practices, constraints, and contextual conditions underlying the quantitative results.

The study followed an explanatory mixed-methods approach in which quantitative results were analyzed first to identify capability strengths and gaps across the nine technological-capability dimensions. Qualitative interviews, observations, and document reviews were then used to explain, interpret, and contextualize the quantitative findings. Integration occurred during the interpretation stage by comparing qualitative evidence with the quantitative capability scores for each dimension. Areas of convergence strengthened the interpretation of the findings, while any inconsistencies were examined to provide additional contextual understanding of the enterprise's technological-capability conditions [23]-[25].

3.2. Data Collection Procedures

Both primary and secondary data were used in this study. Primary data were collected through questionnaires, semi-structured interviews, and direct observation. Secondary data were obtained from company reports, operational records, and technology-related documents. These multiple sources of evidence supported triangulation of the findings.

A census survey was conducted among all 72 employees in the production, maintenance, and quality departments who were directly involved in technology utilization, equipment operation and maintenance, quality control, or day-to-day production activities and who were available and willing to respond. The respondents included 45 production employees, 19 maintenance employees, and 8 quality employees.

Engineering personnel were excluded from the questionnaire because their number was limited and their duties differed substantially from those of production, maintenance, and quality employees. However, their perspectives were included through key-informant interviews.

Five key informants were purposively selected: the General Manager, Production Manager, Maintenance Manager, Quality Control Manager, and Senior Technical Expert. They were selected because of their direct involvement in technology management, technical decision-making, production, maintenance, and quality activities.

The interviews focused on technology planning, acquisition, implementation, utilization, organizational learning, external collaboration, technological constraints, and opportunities for capability improvement.

3.3. Instrument Validity and Reliability

The questionnaire was adapted from the Technological Capability Assessment Framework of Arnold and Thuriaux (1997) [9]. The framework consists of nine dimensions: technology awareness, technology search, core competence, technology strategy, assessment and selection capability, acquisition capability, implementation capability, learning capability, and external linkages.

A structured questionnaire containing 24 items was developed and contextualized to the operational conditions of MIE-Gelan Manufacturing Plant. The questionnaire items were adapted to reflect the terminology, organizational structure, and technological activities of the case-study enterprise while preserving the conceptual meaning of the original framework dimensions. Each item was assigned to one technological-capability dimension according to its primary conceptual emphasis. This item allocation avoided double counting in the calculation of dimension-level and overall technological-capability scores. The operationalization of the nine technological-capability dimensions, including the corresponding questionnaire items and number of items assigned to each dimension, is presented in **Table 1**.

The complete questionnaire, including questionnaire items, source information, adaptation rationale, and allocation to the nine technological-capability dimensions, is provided in Appendix. All questionnaire items were adapted from Arnold and Thuriaux's (1997) Technological Capability Assessment Framework and contextualized to the operational environment of MIE-Gelan Manufacturing Plant.

The number of questionnaire items differs across dimensions because the allocation follows the conceptual structure of the Technological Capability Assessment Framework developed by Arnold and Thuriaux (1997). Broader dimensions, such as External Linkages, require multiple indicators to capture relationships with suppliers, customers, research institutions, government agencies, and industry networks, whereas more focused dimensions, such as Technology Awareness, require fewer indicators. To avoid bias arising from unequal item numbers,

Table 1. Operationalization of technological capability dimensions.

Technological Capability Dimension	Questionnaire Items	Number of Items
Technology Awareness	Q2	1
Technology Search	Q3-Q4	2
Core Competence	Q5-Q6	2
Technology Strategy	Q1, Q7-Q9	4
Assessment and Selection Capability	Q10, Q16	2
Acquisition Capability	Q11-Q12	2
Implementation Capability	Q14-Q15	2
Learning Capability	Q17-Q18	2
External Linkages	Q13, Q19-Q24	7
Total	Q1-Q24	24

Source: Developed by the researcher based on Arnold and Thuriaux (1997).

dimension scores were calculated using average item scores rather than total scores, ensuring that no dimension received greater weight solely because it contained more questionnaire items.

Content validity was assessed through expert review by three specialists with expertise in technology management, manufacturing engineering, and industrial research. The reviewers evaluated the relevance, clarity, contextual suitability, and alignment of the questionnaire items with the nine technological-capability dimensions. Based on their feedback, several items were reworded, overlapping statements were refined, and minor modifications were made before final administration of the questionnaire [26].

A pilot test was conducted with 20 participants who had characteristics similar to those of the target respondents. The pilot assessed item clarity, comprehensibility, and contextual suitability. Based on participant feedback, ambiguous terms were simplified, and minor formatting adjustments were made to improve readability and consistency. No major structural changes to the questionnaire were required [27].

Reliability was assessed using Cronbach's alpha. The overall 24-item questionnaire produced a Cronbach's alpha coefficient of 0.855, indicating good internal consistency for the instrument as a whole. However, the technological-capability assessment framework comprises nine conceptually distinct dimensions rather than a single unidimensional construct. Therefore, the overall Cronbach's alpha should not be interpreted as evidence that all dimensions form one internally consistent scale.

Several dimensions were measured using one or two questionnaire items, making dimension-specific reliability estimation impractical. Consequently, these dimensions were treated as descriptive capability indicators rather than multi-item psychometric scales. The primary purpose of the instrument was to assess tech-

nological-capability conditions across the nine dimensions of the Arnold and Thuriaux (1997) framework rather than to develop a single latent measurement scale. Reliability evidence was therefore interpreted in conjunction with the conceptual structure of the framework, expert review, and pilot testing.

3.4. Ethical Considerations

Ethical principles were observed throughout the study. Participants were informed about the purpose of the research, and participation was voluntary. Personal identifiers were excluded from questionnaires, interview records, analysis, and reporting to protect confidentiality.

Permission to conduct the study was obtained from the management of Mesfin Industrial Engineering PLC-Gelan Manufacturing Plant. Participants were informed of the study objectives, the voluntary nature of participation, and the confidential treatment of their responses. Verbal informed consent was obtained before questionnaire administration and interviews.

All information collected was used only for academic purposes. Participation or non-participation did not affect employees' work status, job responsibilities, or relationship with enterprise management.

3.5. Data Analysis and Scoring Procedure

Quantitative and qualitative data were analyzed using complementary procedures. Quantitative analysis included frequencies, percentages, proportionally weighted scores, item-level capability scores, dimension-level capability scores, and an overall technological capability score. Qualitative data from interviews, observations, and document reviews were analyzed thematically to explain and triangulate the quantitative findings.

The questionnaire contained 24 items representing the nine technological-capability dimensions of Arnold and Thuriaux's (1997) framework. Item-level response frequencies, proportionally weighted scores, and capability scores were calculated for all 24 questionnaire items. The results obtained from the item-level, dimension-level, and overall technological-capability analyses are presented and discussed in Chapter 4.

Responses were measured using a four-point Likert scale: Strongly Disagree, Disagree, Somewhat Agree, and Strongly Agree. The four-point scale was used to avoid neutral responses and encourage respondents to provide a clear assessment of technological-capability conditions in the enterprise [28]. However, because there was no neutral or "do not know" option, the results were interpreted as perception-based indicators rather than direct measures of the enterprise's actual technological capability. The questionnaire response categories, corresponding scale values, and proportional weights used in the analysis are presented in **Table 2**.

The proportional weights were derived directly from the four-point Likert scale by dividing each scale value by the maximum scale value (4), producing equivalent scores of 0.25, 0.50, 0.75, and 1.00. This linear transformation converts Likert-scale

Table 2. Questionnaire response categories and proportional weights.

Response Category	Scale Value	Proportional Weight
Strongly Disagree (SD)	1	0.25
Disagree (D)	2	0.50
Somewhat Agree (SWA)	3	0.75
Strongly Agree (SA)	4	1.00

responses into percentage-based capability scores while preserving the relative ordering and proportional differences among responses. Consequently, the resulting percentage scores are mathematically equivalent to the original Likert-scale means and do not alter the ranking of technological-capability dimensions.

3.5.1. Item-Level Capability Score

The item-level capability score was calculated using the following formula:

$$ICS_i = \left[\frac{(0.25 \times SD_i) + (0.5 \times D_i) + (0.75 \times SWA_i) + (1.00 \times SA_i)}{N} \right] \times 100 \quad (3.1)$$

where:

- ICS_i = item-level capability score for item i ;
- SD_i = number of respondents selecting Strongly Disagree for item i ;
- D_i = number of respondents selecting Disagree for item i ;
- SWA_i = number of respondents selecting Somewhat Agree for item i ;
- SA_i = number of respondents selecting Strongly Agree for item i ;
- N = total number of respondents.

Because all 72 respondents completed the questionnaire, $N = 72$ was used in the item-level calculations.

3.5.2. Dimension-Level Capability Score

The capability score for each technological-capability dimension was calculated by averaging the item-level capability scores assigned to that dimension:

$$DCS_j = \frac{\sum_i^{K_j} ICS_i}{k_j} \quad (3.2)$$

where:

- DCS_j = capability score for the technological-capability dimension j ;
- ICS_i = item-level capability scores for item i ;
- K_j = number of questionnaire items assigned to dimension j .

For example, the Technology Strategy dimension consisted of four items: Q1, Q7, Q8, and Q9. Its capability score was calculated as:

$$DCS_{\text{Technology strategy}} = \frac{ICS_{Q1} + ICS_{Q7} + ICS_{Q8} + ICS_{Q9}}{4} \quad (3.3)$$

3.5.3. Overall Technological Capability Score

The overall technological capability score was calculated from the total propor-

tional weighted score across all 24 questionnaire items:

$$OTCS = \left(\frac{TWS}{N \times K} \right) \times 100 \quad (3.4)$$

where:

$OTCS$ = overall technological capability score;

TWS = total proportional weighted score from all questionnaire items;

N = total number of respondents;

K = total number of questionnaire items.

$$\text{For this study } OTCS = \left(\frac{948}{72 \times 24} \right) \times 100$$

$$OTCS = 54.86\%$$

Mesfin Industrial Engineering PLC-Gelan Manufacturing Plant obtained an overall technological capability score of 54.86%. As a sensitivity check, percentage-based capability scores were compared with the corresponding original Likert-scale means. The comparison produced identical rankings across all nine technological-capability dimensions, indicating that the identification of capability strengths, weaknesses, and improvement priorities was not affected by the score-transformation procedure. Based on the classification in **Table 3**, this score indicates a low level of technological capability.

Table 3. Technological capability classification.

Capability Classification	Score Range
Low Capability	25.00% - 59.99%
Moderate Capability	60.00% - 79.99%
High Capability	80.00% - 100.00%

The capability-classification thresholds were derived from the percentage equivalents of the four-point Likert scale used in the study. Scores below 60% correspond approximately to responses concentrated between Strongly Disagree and Disagree and were classified as low capability. Scores between 60% and 79.99% correspond approximately to responses between Disagree and Somewhat Agree and were classified as moderate capability. Scores of 80% and above correspond to responses approaching Strongly Agree and were classified as high capability. These thresholds were used as analytical criteria for interpreting relative capability levels within the case-study enterprise and do not represent universal industrial benchmarks.

Based on **Table 3**, the overall score of 54.86% indicates a low level of technological capability.

3.5.4. Qualitative Data Analysis

Qualitative data from interviews, observations, and document reviews were analyzed thematically [29]. Semi-structured interviews were conducted in Amharic

with five purposively selected key informants. Interview responses were documented through detailed interview notes and, where permission was granted, audio recordings. The interview records were subsequently translated from Amharic into English for analysis. The researcher reviewed the interview records, observation notes, and organizational documents and conducted thematic coding based on the nine technological-capability dimensions of Arnold and Thuriaux's (1997) framework. Codes were reviewed repeatedly during analysis to ensure consistency between the interview records, observation notes, documentary evidence, and the resulting themes. Documentary sources included available organizational reports, operational records, maintenance-related records, and technology-related documents relevant to technology management, production, maintenance, and organizational learning activities.

The evidence was coded and organized according to the nine technological-capability dimensions of Arnold and Thuriaux's (1997) framework.

The qualitative findings were used to explain and triangulate the quantitative results [30]. Integration occurred at the interpretation stage, where qualitative evidence was compared with the quantitative scores across the nine dimensions.

4. Result and Findings

4.1. Respondent Characteristics

A total of 72 employees participated in the study, resulting in a response rate of 100%. All questionnaires were complete; therefore, no missing-data treatment was required.

The respondents were drawn from the production, maintenance, and quality departments. Production employees constituted the largest proportion of respondents (62.5%), followed by maintenance employees (26.4%) and quality employees (11.1%). These departments were included because they are directly involved in technology utilization, equipment operation, production, maintenance, quality control, and day-to-day technological problem-solving.

Regarding educational level, most respondents possessed Technical and Vocational Education and Training (TVET) qualifications, followed by bachelor's and master's degrees. Most respondents had between three and seven years of work experience, indicating familiarity with the plant's operational and technological activities.

Overall, the respondent profile was appropriate for assessing the plant's technological capability. The demographic characteristics of the respondents are presented in **Table 4**.

4.2. Overall Aggregated Employee-Assessed Technological Capability

Research Question 1

What is the aggregated employee-assessed level of technological capability at Mesfin Industrial Engineering PLC-Gelan Manufacturing Plant?

Table 4. Demographic characteristics of respondents.

Variable	Category	Frequency	Percentage (%)
Educational Level	TVET	40	55.6
	Bachelor's Degree	26	36.1
	Master's Degree	6	8.3
Work Experience (Years)	2	5	6.9
	3	13	18.1
	4	15	20.8
	5	7	9.7
	6	3	4.2
	7	10	13.9
	8	7	9.7
	9	8	11.1
	14	4	5.6
Department	Production	45	62.5
	Maintenance	19	26.4
	Quality	8	11.1
Total		72	100.0

Source: Survey Data, 2026.

The overall technological capability of Mesfin Industrial Engineering PLC-Gelana Manufacturing Plant was assessed using 24 questionnaire items covering nine technological capability dimensions based on the framework of Arnold and Thuriaux (1997). Each item was assessed using a four-point response scale with proportional weights of 0.25, 0.50, 0.75, and 1.00.

The study included 72 respondents. The maximum possible weighted score for each item was therefore 72, assuming that all respondents selected the highest weight of 1.00. The total weighted score across the 24 assessment items was 948.00.

The maximum possible total score was calculated as follows:

$$\text{Maximum Possible Total Score} = N \times K = 72 \times 24 = 1728$$

where N is the total number of respondents and K is the total number of questionnaire items.

The overall technological-capability score was calculated using the formula presented previously in Equation (3.4):

$$OTCS = \left(\frac{TWS}{N \times K} \right) \times 100$$

where:

- $OTCS$ = Overall Technological Capability Score;
- TWS = Total Weighted Score;

- N = Number of Respondents;
- K = Number of Questionnaire Items.

Substituting the study values into Equation (3.4), where $TWS = 948$, $N = 72$, and $K = 24$, gives:

$$OTCS = \left(\frac{948}{72 \times 24} \right) \times 100 = 54.86\%$$

The plant achieved an overall technological capability score of 54.86%. According to the classification adopted in this study, scores between 25.00% and 59.99% represent low capability. Therefore, the plant's overall technological capability was classified as low. The detailed results of the overall technological-capability assessment are presented in **Table 5**.

Table 5. Overall technological capability assessment result.

Indicator	Value
Number of assessment items	24
Number of respondents	72
Total weighted score	948.00
Maximum possible total score	1,728.00
Average weighted score per item	39.50
Overall technological capability score	54.86%
Capability classification	Low capability

The score indicates that the plant has some technological capability foundations, but these capabilities are not yet sufficiently developed or systematically integrated. The findings suggest limitations in technology awareness and search, technology assessment and selection, acquisition, organizational learning, and external technological collaboration.

The overall score provides a general assessment of the plant's technological capability but does not reveal the relative performance of the nine capability dimensions. Section 4.3 therefore examines each dimension separately to identify the plant's relative strengths and weaknesses.

4.3. Strengths and Capability Gaps across the Nine Technological-Capability Dimensions

Research Question 2

What are the major strengths and capability gaps across the nine technological-capability dimensions at Mesfin Industrial Engineering PLC-Gelan Manufacturing Plant?

The nine technological capability dimensions were assessed using 24 questionnaire items developed from the technological capability framework of Arnold and Thuriaux (1997). Each item was assigned to the dimension that best reflected its

primary conceptual meaning.

For each dimension, the Average Weighted Score was first obtained from the weighted scores of the questionnaire items belonging to that dimension. This Average Weighted Score is the raw value obtained directly from the survey data before any further transformation. It represents the average weighted score of all questionnaire items assigned to a particular technological-capability dimension.

The dimension-level capability score was then calculated using the procedure presented in Equation (3.2) in Chapter Three. In operational terms, the Average Weighted Score for each dimension was converted into a percentage by dividing it by the total number of respondents and multiplying the result by 100. This operational expression was used to convert the Average Weighted Score of each technological-capability dimension into its corresponding percentage capability score. The calculation was expressed as follows:

$$DCS_j = \left(\frac{AWS_j}{N} \right) \times 100$$

where:

- DCS_j = dimension-level capability scores for dimension j ;
- AWS_j = average weighted score j ;
- N = total number of respondents.

Since the study included 72 respondents, $N = 72$ was used in calculating the percentage score for each dimension.

For example, the Technology Awareness score was calculated as follows:

$$DCS_{\text{Technology Awareness}} = \frac{37.50}{72} \times 100 = 52.08\%$$

This calculation shows that the raw Average Weighted Score of 37.50 corresponds to a dimension-level capability score of 52.08%. The same calculation procedure was applied to the remaining eight technological-capability dimensions.

The results for all nine technological capability dimensions are presented in **Table 6**.

The results show limited variation among the nine dimensions, as eight dimensions fall within the low-capability category. This indicates that improvement is needed across most technological capability areas.

Implementation Capability recorded the highest score (62.85%) and was the only dimension classified as moderate capability. It is therefore the plant's main relative strength. This result suggests that the plant is comparatively better able to organize and carry out technology-related activities.

However, this moderate score does not indicate a fully developed implementation system. It only shows that Implementation Capability performed better than the other dimensions. The plant should strengthen its implementation practices by linking them with technology planning, assessment and selection, organizational learning, and external collaboration.

Acquisition Capability recorded the second-highest score (57.47%), followed by

Table 6. Dimension-level technological capability assessment.

No.	Capability Dimension	Assessment Items	Average Weighted Score	Score (%)	Capability Classification
1	Technology Awareness	Q2	37.50	52.08	Low capability
2	Technology Search	Q3-Q4	39.50	54.86	Low capability
3	Core Competence	Q5-Q6	41.25	57.29	Low capability
4	Technology Strategy	Q1, Q7-Q9	39.75	55.21	Low capability
5	Assessment and Selection Capability	Q10, Q16	37.38	51.91	Low capability
6	Acquisition Capability	Q11-Q12	41.38	57.47	Low capability
7	Implementation Capability	Q14-Q15	45.25	62.85	Moderate capability
8	Learning Capability	Q17-Q18	39.13	54.34	Low capability
9	External Linkages	Q13, Q19-Q24	37.68	52.33	Low capability

Note: Low capability = 25.00% - 59.99%; Moderate capability = 60.00% - 79.99%; High capability = 80.00% - 100.00%. Source: Survey Data, 2026.

Core Competence (57.29%). Although these dimensions performed relatively better than most low-capability dimensions, both remain below the 60.00% threshold for moderate capability. The findings indicate that the plant has some ability to acquire technological resources and maintain internal technical competence, but further improvement is required.

Technology Strategy scored 55.21%, while Technology Search scored 54.86%. These results indicate that the plant has some, but limited, capacity to establish technology priorities and identify technological opportunities. However, technology planning may not yet be systematic or sufficiently integrated with the plant's long-term objectives.

Learning Capability recorded a score of 54.34%. This indicates weaknesses in post-project review, knowledge documentation, experience sharing, and the transfer of lessons between technology-related activities. These weaknesses may reduce the plant's ability to absorb new technologies, address implementation problems, and improve through operational experience.

External Linkages scored 52.33%. This suggests that relationships with suppliers, universities, research institutions, consultants, government agencies, and other support organizations are not sufficiently developed or strategically managed. Strengthening these relationships could improve access to technical information, training, technology transfer, technical assistance, and collaborative problem-solving.

Technology Awareness scored 52.08%. This indicates limited awareness of technological developments, emerging technologies, risks, and opportunities. Improved technology awareness would enable the plant to identify relevant changes

earlier and respond more effectively.

Assessment and Selection Capability recorded the lowest score (51.91%). This is the plant's most significant capability gap. The result indicates weaknesses in evaluating, comparing, prioritizing, and selecting technology alternatives. Weak assessment and selection procedures may result in technology choices that do not adequately match the plant's operational needs, financial capacity, technical skills, or long-term objectives.

4.4. Capability in Technology Assessment and Selection, Acquisition, Implementation, Organizational Learning, and External Linkages

Research Question 3

What is the level of capability in technology assessment and selection, technology acquisition, technology implementation, organizational learning, and external technological linkages?

The plant's capability to acquire, absorb, adapt, and improve transferred technologies was assessed using five related technological-capability dimensions: Assessment and Selection Capability, Acquisition Capability, Implementation Capability, Learning Capability, and External Linkages. Together, these five dimensions reflect the organizational capabilities required to assess and select appropriate technologies, acquire them from relevant sources, implement them effectively, learn from operational experience, and obtain external technical support. These capabilities are essential for the effective acquisition, absorption, adaptation, and improvement of transferred technologies.

The five dimensions were measured using 15 questionnaire items. Since the dimensions contained different numbers of assessment items, an item-weighted average was used to calculate the composite score. This ensured that each questionnaire item contributed equally to the composite assessment.

The composite average weighted score was calculated using the following formula:

$$CAWS = \frac{\sum_{j=1}^m (AWS_j \times K_j)}{K} \quad (4.1)$$

where:

- $CAWS$ = composite average weighted score;
- AWS_j = average weighted score for dimension j ;
- K_j = number of assessment items assigned to dimension j ;
- K = total number of assessment items included in the composite score;
- m = number of technological capability dimensions included in the composite assessment.

For this study:

$$CAWS = \frac{(37.38 \times 2) + (41.38 \times 2) + (45.25 \times 2) + (39.13 \times 2) + (37.68 \times 7)}{15}$$

$$CAWS = 39.34$$

The composite capability score was then calculated by applying the percentage-conversion procedure presented in Equation (3.2):

$$CCS = \left(\frac{CAWS}{N} \right) \times 100$$

where:

- CCS = composite capability score;
- $CAWS$ = composite average weighted score;
- N = total number of respondents.

Therefore:

$$CCS = \left(\frac{39.34}{72} \right) \times 100 = 54.63\%$$

The item-weighted calculation produced a composite average weighted score of 39.34, reported to two decimal places. The final composite capability score was calculated using the intermediate value before it was rounded, resulting in a composite capability score of 54.63%. According to the classification adopted in this study, this score represents low capability.

The component scores used to calculate the composite result are reported in **Table 6**. Assessment and Selection Capability scored 51.91%, Acquisition Capability scored 57.47%, Implementation Capability scored 62.85%, Learning Capability scored 54.34%, and External Linkages scored 52.33%. Because these dimensions contained different numbers of questionnaire items, the composite score was calculated using an item-weighted average rather than a simple average of the five-dimension scores.

Implementation Capability recorded the highest score (62.85%) and was the only dimension classified as moderate capability. It therefore represents the plant's main relative strength within this capability group. This finding suggests that the plant is comparatively better at implementing technology-related activities than at selecting technologies, acquiring technological resources, learning from implementation experience, and obtaining external technical support.

However, the moderate Implementation Capability score does not indicate a fully developed implementation system. It shows only that this dimension performed better than the other four dimensions included in the assessment.

Acquisition Capability recorded the second-highest score (57.47%) but remained within the low-capability category. This indicates that the plant has some capacity to acquire technological resources, although this capacity requires further development.

Learning Capability scored 54.34%, indicating limitations in employee learning, technical knowledge documentation, experience sharing, and the application of lessons from previous technology-related activities. These limitations may restrict the plant's ability to absorb, adapt, and improve transferred technologies.

External Linkages scored 52.33%, suggesting limited collaboration with suppliers, universities, research institutions, consultants, government agencies, and

other technology-support organizations. This may restrict access to specialized knowledge, training, technical assistance, and collaborative problem-solving.

Assessment and Selection Capability recorded the lowest score (51.91%). It therefore represents the most significant capability gap among the five dimensions. Weak technology-assessment and selection procedures may result in the acquisition of technologies that do not adequately match the plant's operational requirements, employee skills, financial capacity, infrastructure, or long-term objectives.

Overall, the composite score of 54.63% indicates that the plant's capability to acquire, absorb, adapt, and improve transferred technologies is low. Although the plant has a relatively stronger ability to implement technology-related activities, weaknesses in assessment and selection, learning, and external linkages limit its ability to achieve sustainable technological upgrading.

Therefore, the plant should prioritize the formal evaluation and selection of technology alternatives, employee training, technical knowledge documentation, post-implementation review, internal knowledge sharing, and collaboration with external technology-support organizations. Its relatively stronger Implementation Capability should be used as a foundation for strengthening these weaker areas and supporting continuous technological improvement.

4.5. Strategic Interventions for Technological Capability Development and Industrial Upgrading

Research Question 4

What strategic interventions may strengthen technological capability and support future industrial upgrading and competitiveness at the plant?

Mesfin Industrial Engineering PLC-Gelan Manufacturing Plant achieved an overall technological capability score of 54.86%, indicating low capability. Of the nine assessed dimensions, Implementation Capability was the only dimension with moderate capability (62.85%), while the remaining dimensions were classified as low capability, ranging from 51.91% to 57.47%.

To determine intervention priorities, the dimensions were ranked according to their relative scores, as presented in **Table 7**. Lower scores generally indicate larger capability gaps and greater urgency for improvement. However, dimensions with very similar scores should not be interpreted as representing substantially different capability levels. Therefore, the priority ranking is intended as a practical guide for improvement planning rather than a precise statistical ordering of the dimensions.

The findings show that Assessment and Selection Capability (51.91%), Technology Awareness (52.08%), and External Linkages (52.33%) represent the lowest-scoring dimensions and therefore warrant particular attention. However, the differences among these scores are very small. Consequently, these dimensions should be interpreted as belonging to a similar capability-gap group rather than as distinctly ranked priorities. Improvement efforts may therefore address these

Table 7. Capability priority matrix for technological capability development.

Priority Level	Capability Dimension	Score (%)	Classification	Strategic Focus
Critical	Assessment and Selection Capability	51.91	Low Capability	Strengthen technology evaluation and selection procedures.
Critical	Technology Awareness	52.08	Low Capability	Improve awareness of technologies, opportunities, and threats.
Critical	External Linkages	52.33	Low Capability	Strengthen collaboration with external technology-support actors.
High	Learning Capability	54.34	Low Capability	Improve training, reviews, documentation, and knowledge sharing.
High	Technology Search	54.86	Low Capability	Strengthen technology scanning and information gathering.
High	Technology Strategy	55.21	Low Capability	Establish formal technology planning and priorities.
Medium	Core Competence	57.29	Low Capability	Strengthen internal technical expertise.
Medium	Acquisition Capability	57.47	Low Capability	Improve technology sourcing and knowledge transfer.
Consolidation	Implementation Capability	62.85	Moderate Capability	Maintain and improve existing implementation practices.

Note: Priority levels reflect relative improvement needs and do not replace the formal capability classifications. Where score differences are minimal, the rankings should be interpreted cautiously as indicative rather than definitive priorities. Source: Survey Data, 2026.

areas concurrently rather than sequentially. Improvement in these areas is necessary to strengthen the plant's ability to identify technological opportunities, evaluate alternatives, select appropriate technologies, and obtain external technical support.

Learning Capability, Technology Search, and Technology Strategy are high-priority areas because they support systematic technology planning, information gathering, knowledge sharing, and continuous improvement. Core Competence and Acquisition Capability also require improvement, although their scores were relatively higher than those of the other low-capability dimensions. Implementation Capability should be consolidated and integrated with planning, learning, acquisition, and external collaboration activities.

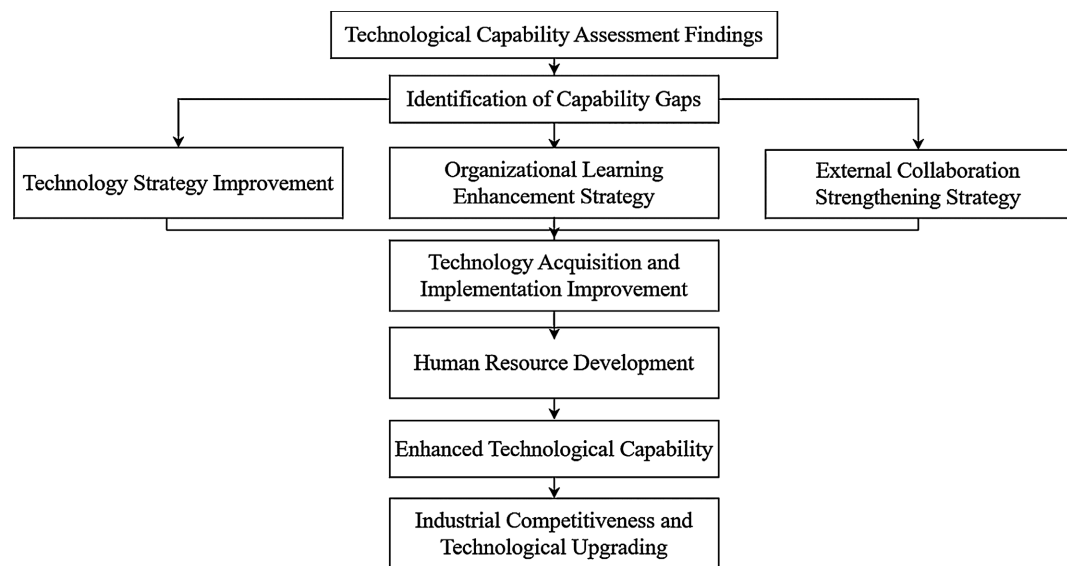
Based on these findings, the plant should establish formal procedures for technology assessment, comparison, selection, and long-term planning. It should also strengthen technology awareness and search activities through regular scanning of technological developments, market information, opportunities, and threats. Employee training, post-project reviews, knowledge documentation, mentoring, and experience-sharing practices should be improved to enhance organizational learning and human-resource development.

Technology acquisition procedures should be strengthened through clear sourcing mechanisms, supplier support, and effective transfer of operational and maintenance knowledge. Collaboration with suppliers, universities, research institutions, consultants, government agencies, and technology providers should

also be enhanced to improve access to technical information, expertise, training, and technical assistance. Existing implementation capability should be maintained while linking project implementation with continuous improvement, employee learning, technology planning, and external support.

The proposed interventions are interrelated. Technology strategy provides direction for technology awareness, search, assessment, acquisition, and implementation. Organizational learning and human-resource development enable employees to use, maintain, adapt, and improve acquired technologies. External collaboration supports access to technical knowledge, expertise, and technology-support services.

Figure 3 presents the relationship between identified capability gaps and strategic interventions in technology strategy, organizational learning, external collaboration, technology acquisition, implementation, and human resource development. These interventions are expected to support improved technological capability, industrial competitiveness, and technological upgrading. The framework is an analytical guide based on the study findings and does not establish statistically confirmed causal relationships.



Source: Developed by the researcher based on the technological capability assessment findings, 2026.

Figure 3. Strategic intervention framework derived from technological capability assessment findings.

4.6. Qualitative Insights from Interviews and Observations

Qualitative data were collected through semi-structured interviews with five purposively selected key informants and direct observations at Mesfin Industrial Engineering PLC-Gelan Manufacturing Plant. The purpose was to explain the organizational, managerial, and technological conditions underlying the quantitative findings. The evidence revealed interconnected challenges related to technology strategy, technology acquisition and modernization, organizational learning, external collaboration, and continued reliance on conventional production practices.

Interview findings indicated that technology-related decisions were largely driven by immediate operational needs rather than systematic long-term planning. One interview participant noted that technology investments were often made in response to immediate production requirements rather than long-term technology plans (Interviewee 1). This reactive approach is consistent with the low Technology Strategy score of 55.21% and may limit the plant's ability to anticipate future technological requirements, plan modernization activities, and align technology investments with organizational objectives.

The interviews and observations also revealed aging equipment, limited upgrading, restricted investment, and difficulties in accessing advanced manufacturing technologies. Available maintenance and operational records reviewed during the study also indicated continued emphasis on equipment maintenance activities rather than major technology-upgrading initiatives. Direct observations showed continued use of aging production equipment, while maintenance activities focused primarily on repairing existing machinery rather than upgrading technological systems. Maintenance activities focused mainly on repairing existing equipment and addressing immediate operational problems. These conditions are consistent with the low Acquisition Capability score of 57.47%, indicating limitations in acquiring new technologies, upgrading existing equipment, and utilizing technological assets effectively.

Organizational learning was another significant limitation. Employees developed technical skills mainly through practical work experience, while structured training, mentoring, knowledge documentation, and formal knowledge-sharing mechanisms remained limited. As one participant explained, most technical knowledge was acquired through workplace experience rather than formal training programs (Interviewee 3). This finding supports the low Learning Capability score of 54.34% and highlights the need to strengthen employee development, knowledge management, and post-project learning.

The qualitative evidence further showed limited interaction with universities, research institutions, suppliers, consultants, and technology providers. Several interview participants reported infrequent collaboration with universities, research institutions, and external technology-support organizations. This finding corresponds with the low External Linkages score of 52.33%. Weak external collaboration may restrict access to technical information, specialized expertise, training, technology-transfer opportunities, and collaborative problem-solving.

Direct observations indicated continued reliance on conventional production practices, with limited evidence of systematic technological innovation and continuous improvement. This finding should be considered alongside the Implementation Capability score of 62.85%, which was the highest score and the only dimension classified as moderate capability. Although the plant demonstrates a relatively stronger ability to implement existing technology-related activities, implementation practices are not yet sufficiently integrated with innovation, technology adaptation, organizational learning, and continuous improvement.

Overall, the qualitative findings provide explanatory support for the quantitative results. The plant's low technological capability appears to be associated with interconnected weaknesses in technology planning, equipment modernization, organizational learning, external collaboration, and continuous improvement. These issues should therefore be addressed through coordinated interventions rather than isolated actions. The findings reinforce the strategic priorities presented in **Table 7** and **Figure 3**, particularly the need to improve long-term technology planning, employee training, knowledge sharing, external collaboration, technology acquisition, equipment modernization, and implementation practices.

Addressing these areas would strengthen the plant's ability to acquire, absorb, adapt, and improve transferred technologies, thereby supporting technological capability development, industrial competitiveness, and technological upgrading. However, the qualitative findings are explanatory in nature and should not be interpreted as statistically confirmed causal relationships.

The qualitative and quantitative findings were largely convergent across the nine technological-capability dimensions. For example, the low scores for Assessment and Selection Capability, Learning Capability, and External Linkages were supported by interview evidence describing limited technology-evaluation procedures, weak knowledge-sharing practices, and restricted collaboration with external technology-support organizations. Similarly, the relatively stronger Implementation Capability score was consistent with observations indicating practical experience in operating existing technologies. No major contradictions were identified between the qualitative and quantitative findings. The qualitative evidence therefore served primarily to explain and contextualize the capability strengths and gaps identified through the survey results.

5. Discussion

The findings show that Mesfin Industrial Engineering PLC-Gelan Manufacturing Plant has a basic operational and technical foundation, but its overall technological capability remains low, with a score of 54.86%. Implementation Capability was the only dimension classified as moderate, scoring 62.85%, whereas the remaining dimensions were rated low. This indicates that the plant is more capable of operating existing technologies than of strategically assessing, acquiring, learning from, adapting, and improving them. The relatively higher implementation score therefore reflects practical experience in using existing technologies rather than a fully developed system for technological upgrading.

The Technology Strategy score of 55.21%, together with the low scores for Assessment and Selection Capability (51.91%) and Acquisition Capability (57.47%), indicates that technology decisions are mainly influenced by immediate production and maintenance needs rather than systematic long-term planning. This reactive orientation may result from limited financial resources, insufficient technology information, weak coordination among management and technical departments, and limited in-house capacity to conduct technical and economic eval-

uations. The acquisition process may also be affected by dependence on imported machinery and spare parts, foreign-exchange constraints, and limited access to supplier-based technical support. Technology acquisition should therefore include supplier evaluation, compatibility analysis, employee preparation, knowledge transfer, maintenance planning, and post-acquisition performance evaluation [31] [32].

Qualitative evidence on aging equipment, restricted investment, limited upgrading, and difficulty accessing advanced technologies further confirms the need for modernization. However, modernization should be accompanied by training, maintenance improvement, process adaptation, knowledge transfer, and operational learning [33]. The equipment problem is therefore not only a financial issue; it also reflects limited renewal planning, restricted technical support, and insufficient capability to integrate and sustain new technologies.

The Learning Capability score of 54.34% indicates weaknesses in structured training, mentoring, documentation, experience sharing, and post-project review. These weaknesses may be associated with limited training budgets, production pressures that reduce opportunities for employee development, the absence of formal training-needs assessment, insufficient managerial emphasis on capability development, and limited access to appropriate external training providers. The plant should therefore establish targeted technical training programs, knowledge-documentation procedures, lessons-learned reviews, and team-based problem-solving activities to transform individual experience into organizational knowledge and strengthen technological learning capability [34].

External Linkages remained low at 52.33%. Stronger cooperation with suppliers, universities, research institutions, consultants, technology providers, and government organizations could improve access to technical expertise, training, testing services, maintenance support, and technology-transfer opportunities [32]. The low Technology Awareness score (52.08%) and Technology Search score (54.86%) further suggest that the plant does not systematically monitor technological developments and emerging opportunities. This limitation may reflect weak university-industry linkages, limited local technology-support services, the cost of consultancy and testing, and insufficient institutional mechanisms for obtaining external knowledge.

African manufacturing studies similarly report weaknesses in technological learning, skills development, and external collaboration [35]-[37]. These findings suggest that capability constraints are common among manufacturing firms operating in developing industrial environments. However, these studies used different indicators, samples, and measurement procedures; therefore, they provide contextual support rather than a direct numerical comparison with the findings of this study. Although most technological-capability dimensions remained low, MIE-Gelan demonstrated relatively stronger implementation capability, indicating that operational experience has developed more rapidly than strategic, learning-related, and technology-management capabilities. This finding should be interpreted primarily within the context of the present case study rather than as evidence

of a general capability-development pattern across African manufacturing firms.

Some challenges identified in this study, including dependence on imported technologies, shortages of skilled personnel, and weak external linkages, reflect conditions reported in studies of manufacturing firms in developing industrial environments [35] [36]. In the Ethiopian context, these challenges may be further influenced by foreign-exchange constraints, limited technology-support services, and dependence on imported equipment and components. In contrast, factors such as the plant's equipment condition, internal training practices, management priorities, and technology-selection procedures are context-specific characteristics of MIE-Gelan and should not be automatically generalized to all Ethiopian manufacturing enterprises.

These findings support the view that technological capability develops through learning, adaptation, experience accumulation, and knowledge acquisition rather than through technology transfer alone [30] [33]. The plant should therefore link technology strategy, assessment, acquisition, implementation, learning, external collaboration, and continuous improvement. Firm-level reforms should focus on technology planning, training-needs assessment, preventive maintenance, knowledge documentation, and post-implementation review, while broader institutional support is required to improve access to finance, technical training, supplier services, research collaboration, and technology information [37].

This study was limited to a single enterprise, used a cross-sectional design, relied partly on perception-based data, and included five qualitative informants. The findings therefore cannot establish causal relationships or be fully generalized to other industrial contexts. Future research should use larger samples, longitudinal designs, objective performance indicators, and comparative studies of Ethiopian and African manufacturing firms.

6. Conclusions and Recommendations

6.1. Conclusions

First, the findings indicate that technological capability at MIE-Gelan is characterized by relatively stronger implementation capability than strategic, learning, and technology-management capabilities. This suggests that operational use of technology may develop faster than technology planning, assessment, acquisition, and organizational learning functions in late-industrializing manufacturing firms.

Second, the study indicates that technology acquisition alone does not guarantee technological upgrading. Sustainable capability development depends on complementary organizational capabilities, including technology planning, employee development, knowledge transfer, maintenance systems, organizational learning, and post-implementation evaluation.

Third, technological capability development appears to be a systemic and inter-dependent process. Technology awareness, technology search, assessment and selection, acquisition, implementation, learning, and external linkages function as mutually reinforcing capabilities. Weaknesses in one area may reduce the effec-

tiveness of the others and limit overall technological upgrading.

Overall, the findings suggest that sustainable technological upgrading at MIE-Gelan requires coordinated improvement in technology strategy, human-resource development, organizational learning, external collaboration, maintenance planning, and continuous improvement.

6.2. Recommendation

Mesfin Industrial Engineering PLC-Gelan Manufacturing Plant should establish a formal technology strategy aligned with its production objectives, modernization priorities, workforce requirements, and long-term development goals. A dedicated technology-management team should coordinate technology planning, assessment, acquisition, implementation, and performance evaluation.

The plant should strengthen organizational learning through regular technical training, mentoring, knowledge-sharing activities, and documented operating procedures. Particular attention should be given to equipment operation, preventive maintenance, quality management, technical problem-solving, and the retention of organizational knowledge.

Technology acquisition and equipment modernization should be guided by systematic technical and economic assessments, including supplier evaluation, compatibility analysis, operator training, maintenance preparation, and post-acquisition performance review. Modernization efforts should prioritize critical and obsolete equipment that constrains production performance.

The plant should also expand collaboration with universities, technical institutions, research organizations, suppliers, and technology providers to improve access to training, technical expertise, maintenance support, innovation, and technology-transfer opportunities.

To sustain capability development, continuous-improvement practices should be institutionalized through preventive maintenance, root-cause analysis, employee participation, and regular performance monitoring. Key indicators such as equipment utilization, downtime, training participation, maintenance completion, and improvement-project outcomes should be tracked.

At the policy level, relevant Ethiopian industrial-development institutions should strengthen support for manufacturing firms through modernization financing, technical-training programs, advisory services, testing facilities, and university-industry collaboration. Future research should examine technological capability across multiple firms and sectors using larger samples, longitudinal designs, and objective performance indicators.

Author Contributions

Haftom Aweke Haftimer: conceptualization, methodology, investigation, data curation, formal analysis, and writing of the original draft preparation. Professor Guo Dong: supervision and writing review and editing, including detailed critical feedback, valuable academic guidance, and substantive revisions throughout the

manuscript. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

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Appendix: Questionnaire Items, Source, Adaptation, and Dimension Allocation

Adaptation rationale: The questionnaire items were adapted to reflect the terminology, organizational structure, and technological activities of Mesfin Industrial Engineering PLC-Gelan Manufacturing Plant while preserving the conceptual meaning of the original technological-capability dimensions.

Item	Questionnaire Statement	Capability Dimension
Q1	Technology plays an important part in my enterprise business strategy.	Technology Strategy
Q2	My enterprise is well aware of the most important technologies for its business.	Technology Awareness
Q3	My enterprise is well equipped to assess technological opportunities.	Technology Search
Q4	My enterprise can assess technology threats without difficulty.	Technology Search
Q5	My enterprise has special technological strengths that it is able to exploit.	Core Competence
Q6	My enterprise knows which technologies to outsource and which to develop internally.	Core Competence
Q7	Our management is skilled at formulating a technology strategy to meet business goals.	Technology Strategy
Q8	Our enterprise knows its main technology priorities.	Technology Strategy
Q9	Our enterprise has a well-developed technology vision.	Technology Strategy
Q10	Our enterprise knows how to select the technology needed for its business.	Assessment and Selection Capability
Q11	Our enterprise knows the best sources of technology.	Acquisition Capability
Q12	Our enterprise is effective at acquiring technology from external sources.	Acquisition Capability
Q13	Our enterprise has good links with important external suppliers of technology.	External Linkages
Q14	Our technology activities, such as engineering and research and development, are organized effectively within our enterprise.	Implementation Capability
Q15	We have clear processes for carrying out technology projects.	Implementation Capability
Q16	Our enterprise has a good system for assessing technology projects.	Assessment and Selection Capability
Q17	Our enterprise carries out post-project reviews.	Learning Capability
Q18	We are able to learn from one technology project to another.	Learning Capability
Q19	Government policies encourage us to invest in technology.	External Linkages
Q20	We use external organizations, such as consultancy firms and technology assessment institutions, to assist us in important technology projects.	External Linkages
Q21	We use outside organizations to help us develop technology.	External Linkages
Q22	External organizations help us assess our technology performance.	External Linkages
Q23	We work with universities in key technology projects.	External Linkages
Q24	We work with government research institutions.	External Linkages

Source: All questionnaire items were adapted from the Technological Capability Assessment Framework developed by Arnold and Thuriaux (1997) [9].