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Effect of 5G-Enabled Real-Time Monitoring on Production Line Flexibility: A Survey of Industry 4.0 Adopters

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Abstract
This research aims to analyze the impact of 5G-enabled real-time monitoring on enhancing production line flexibility within an Iraqi industrial environment, through a case study at the General Company for Electrical and Electronic Industries. The study adopted a descriptive analytical methodology using a structured questionnaire covering three dimensions of the independent variable (Connectivity and Data Transmission, Data Accuracy and Monitoring Quality, Decision-Making and Response Time), along with the dependent variable (Production Line Flexibility). The questionnaire was distributed to a sample of 188 employees, and data were analyzed using SPSS (version 29). The statistical methods included reliability and validity testing (Cronbach's Alpha), Pearson correlation analysis, multiple linear regression, and model diagnostic tests (VIF, Bartlett's Test, Kolmogorov–Smirnov Test). The results revealed a strong and statistically significant relationship between the dimensions of real-time monitoring and production flexibility, with an overall correlation coefficient of 0.774. The regression model explained 62.9% of the variance in the dependent variable. This study is distinguished by providing field data from a developing industrial setting, adding practical value to existing literature.

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Keywords: 5G, Real-Time Monitoring, Production Flexibility, Industry 4.0, Iraq

Introduction

The world now observes extensive adoption of fifth-generation (5G) technologies throughout multiple industrial sectors since the last few years. Through this technology users can experience superior data transfer speeds and minimal delay times with the added capability of processing dense real-time operations. Modern production needs these attributes because they help perform precise decision-making under sudden changes (Cheng *et al*., 2024) [3]. The implementation of Fourth Industrial Revolution principles by industries depends on instant machine-system-user communication that edge computing and distributed 5G architecture enables (Dolgui and Ivanov, 2022) [4]. Real-time production monitoring using 5G technology enhances production line flexibility based on three essential components which improve data processing speed and delay-free communication among production units (Rodriguez *et al*., 2021) [13]. In current operational decision-making it is crucial to secure real-time information accuracy since it enables immediate evidence-based management choices (Ganesh 2021; Hu *et al*. 2024) [5, 7]. The third advantage of Industrial Internet of Things implementation enables fast operational adjustments to production lines through quick response times for addressing operational problems and demand fluctuations (Lundgren *et al*., 2022) [8].

The proven success of these applications from industrialized countries has not solved implementation hurdles because developing countries like Iraq still confront obstacles with their digital infrastructure and technical resources and institutional adaptability. An evaluation of 5G technology implementation within local industrial companies must occur because it affects operational flexibility while addressing complex issues in Iraq's workplace structure. Various studies recognize the necessity of analyzing these effects because they help organizations transition from legacy manufacturing practices to digital modes (Metelenko *et al*., 2023; Mahajan and Kaur, 2024) [10, 9]. Accordingly, this study aims to provide a field analysis of the impact of 5G-enabled real-time monitoring on the flexibility of production lines at the General Company for Electrical and Electronic

Industries in Iraq, one of the organizations that has begun adopting components of Industry 4.0 technologies. The study aims to answer a fundamental question: To what extent does the integration of 5G-enabled real-time monitoring contribute to improving the ability to respond, plan, and adapt to production lines within the local context?

Research problem

Although recent studies have demonstrated the positive impact of 5G technologies in supporting real-time monitoring and enhancing the flexibility of production lines in advanced industrial environments, the extent to which these benefits are realized in the industrial contexts of developing countries, including Iraq, remains unclear. The flexibility of production lines is a crucial factor in improving the efficiency of industrial operations and responding to fluctuations in demand and operating conditions. However, the implementation of 5G technologies requires advanced digital infrastructure, qualified human and technical resources, and a regulatory environment capable of keeping pace with the digital transformation. Given the limited application studies in the Iraqi context and the lack of field evidence on the effectiveness of this technology in enhancing local industrial performance, there is a need to investigate the relationship between the use of real-time monitoring via 5G and the flexibility of production lines in Iraqi organizations, to understand the challenges, opportunities, and practical implications of this transformation**.** Accordingly, the research problem is the following question**:** To what extent does real-time monitoring based on 5G technology enhance the flexibility of production lines at the General Company for Electrical and Electronic Industries in Iraq?

Hypothesis

Main Hypothesis

There is a statistically significant relationship between the implementation of real-time monitoring based on 5G technology and the flexibility of production lines at the General Company for Electrical and Electronic Industries in Iraq**.**

Sub-Hypotheses

1. There is a statistically significant relationship between improved communication and data transmission using 5G and the flexibility of production lines**.**
2. There is a statistically significant relationship between the accuracy of data and the quality of real-time monitoring supported by 5G and the flexibility of production lines**.**
3. There is a statistically significant relationship between the speed of decision-making and the reduction of response time via 5G and the flexibility of production lines.

Literature Review

Litigation about fifth-generation (5G) technologies reveals their power to advance industrial performance by enhancing production line flexibility and time management. The "5G Swarm Production" framework allows mass production systems to use wireless automation and real-time intelligent control which provides immediate responses to operational changes according to Rodriguez *et al*. (2021) [13]. Using 5G within digital supply chains creates a combined communication network which both improves adaptive planning methods and minimizes delays according to Dolgui and Ivanov (2022) [4]. The authors of Cheng *et al*. (2024) [3] conducted research on how the manufacturing industry relies more heavily on 5G technology for predictive maintenance and intelligent factory control systems. Other research has focused on the technical dimensions of 5G applications. Ganesh (2021) [5] demonstrated that integrating 5G into industrial infrastructure increases the efficiency of machine-to-machine communications, accelerates data flow, and reduces gaps in monitoring and analysis. Hu *et al*. (2024) [7] demonstrated that real-time monitoring applications using 5G in precision manufacturing processes, such as milling, contributed to improved quality and reduced operational errors. Lundgren *et al*. (2022) [8] applied a modified TOPSIS methodology and demonstrated that the use of 5G led to a significant improvement in industrial performance indicators, including operational efficiency and production flexibility**.** In the organizational field, Metelenko *et al*. (2023) [10] indicated that 5G-enabled digital transformation requires redesigning industrial management structures to become more flexible, which supports the alignment between technology and institutional capabilities. From the perspective of healthcare and related industries, studies such as Mahajan and Kaur (2024) [9] and Vimal *et al*. (2024) [15] have highlighted the importance of 5G in supporting time-sensitive applications, especially in environments requiring high accuracy and immediate response. This can also be applied to the industrial context. Pappala *et al*. (2024) [11] also confirmed that 5G is not just a communications technology, but a platform for transformation across various industrial and service sectors by supporting big data and the Internet of Things**.** In light of the above, it can be said that the theoretical framework surrounding 5G and production flexibility has advanced significantly. However, applying these findings in developing contexts, such as Iraq, still requires field studies that shed light on local challenges and contexts, which this study seeks to address.

Spatial and temporal limits

The spatial boundaries of this study are defined within the General Company for Electrical and Electronic Industries in Iraq, given that it is one of the industrial establishments that has actually begun adopting components of Fourth Industrial Revolution technologies, including some smart monitoring applications in production lines. The selection of this establishment is scientifically justified by its representation of a realistic model of a semi-advanced Iraqi industry in terms of its administrative and technical structure. This provides a suitable environment for testing the relationship between 5G applications and production flexibility, given relatively limited technical and human resources—characteristics that reflect the nature of many industrial establishments in developing countries**.** In terms of temporal boundaries, the study was conducted during the first three months of 2025, a period that witnessed relative stability in operational activities within the company after the introduction of some technical updates related to the digital infrastructure. This made the timing appropriate for observing the impact of using 5G technology on real-time monitoring within a normal operating environment unaffected by external disruptive factors, such as seasonal fluctuations or emergency production outages.

Methodology

This study adopted the descriptive-analytical approach, as it is the most appropriate for examining and interpreting the relationships between variables within a realistic environment without interfering with the flow of production processes. This approach allows for describing the phenomenon as it is and analyzing the relationship between real-time monitoring applications using 5G technology and the flexibility of production lines. Primary data was collected using a scientifically designed questionnaire based on standards adopted in previous literature. The survey featured both an independent variable axis (real-time monitoring through 5G technology) with its three components along with a dependent variable axis (production line adaptability). A group of experienced judges evaluated the five-point Likert scale questionnaire to confirm both theoretical validity and linguistic accuracy before distribution. The research instrument was given to a selected group of employees who worked for the company. The research team used SPSS version 29 to welcome and analyze the acquired data. The research tool underwent validity assessments through reliability and validity tests which also allowed for Pearson Correlation and Multiple Linear Regression analysis to measure variable interrelations and independent variable influence on production line functionality. The validity of the statistical model's usage was checked through diagnostic tests which evaluated multicollinearity together with autocorrelation and residual distribution. Research methodology comprised steps which began with creating the theoretical model then designed the tool followed by data acquisition and analysis and concluding with interpretation of results aligned to research objectives.

Population and Sample

The study population was defined as all employees of the General Company for Electrical and Electronic Industries in Iraq who are directly involved in production processes or hold managerial and technical positions that enable them to evaluate the impact of real-time monitoring using 5G technology on the flexibility of production lines. To ensure adequate statistical representation, the minimum sample size was calculated using the approved sampling equation for limited population research at a 95% confidence level and a 5% margin of error. The minimum required sample size was 175 individuals. However, to enhance the credibility of the results and increase the power of the statistical analysis, the questionnaire was distributed to 188 individuals from the population, all of whom were returned in full and included in the analysis. This sample size is sufficient to ensure the generalizability of the results to the original population within the study's boundaries and allows for rigorous analytical tests to detect differences and relationships between the variables under study:

$$n = \frac{N}{1+N(e^2)}$$

n = Required sample size, N = Total population size, e = Margin of error (typically set at 5% or 0.05 for a 95% confidence level).

$$n = \frac{350}{1+350(0.05^2)} = 175.7$$

The Theoretical Concept of the Research

The study uses 5G-Enabled Real-Time Monitoring (5G-Enabled Real-Time Monitoring) as its independent variable to observe the impact on dependent variable Production Line Flexibility (PL). 5G platform connectivity allows near real-time data transfer at enhanced speed rates and small-time delays by joining numerous industrial devices to support production process monitoring (Cheng *et al*., 2024; Ganesh, 2021) [3, 5]. Technical production efficiency along with reduced equipment failures and faster adjustments to changes operate as fundamental factors that make 5G crucial for industrial operations. This variable helps organizations achieve predictive maintenance and data-driven decision-making through analytics (Hu *et al*., 2024; Dolgui and Ivanov, 2022) [7, 4]. The independent variable exists in three principal components. The first aspect of 5G network quality involves "communication and data transfer" to enhance the performance of data exchange between users and improve network latency and real-time data operations (Rodriguez *et al*., 2021) [13]. The second component of "data accuracy and monitoring quality" shows how the system creates precise detailed process information which enables the early detection of production abnormalities to minimize losses from procedure delays or mistakes (Lundgren *et al*., 2022) [8]. Management speed and time needed for decision-making serves as a third dimension that measures organizational data-driven decision capacity to modify procedures and recalibrate machines without interrupting operational activities (Metelenko *et al*., 2023) [10].

The dependent variable production line flexibility defines the speed at which organizations can change operational plans or shift between products while maintaining efficiency and quality standards. Production flexibility's crucial role among today's businesses has grown stronger since it acts as a key survival measure for adapting to market uncertainties and customer market trends in competitive industrial settings (Dolgui and Ivanov, 2022) [4]. Organizations using 5G advanced technologies can collect real-time information to support flexible operational decisions directly because these technologies enable real-time information collection and analytical capabilities (Mahajan and Kaur, 2024; Pappala *et al*., 2024) [9, 11]. Knowledge of the connection between these two variables enables researchers to understand the potential advantages of 5G adoption and find new opportunities for industrial system development in developing environments.

Discussion and results

1. Study tool

The researcher utilized a structured questionnaire designed to evaluate how 5G-enabled real-time monitoring affects production line flexibility as the primary data collection instrument. The questionnaire contained three main sections for data collection. Demographic information such as gender along with age and education background and years of experience was gathered in the initial section to support response classification and profile analysis. Five G-enabled real-time monitoring was analyzed through the independent variable in the second section which contained three parts: Connectivity with data transmission elements and Data accuracy alongside monitoring quality together with decision making and response time aspects. Each dimension provided five items that allowed participants to evaluate 5G technology effectiveness by answering questions on a 5-point Likert scale with extreme points ranging from "Strongly

Disagree" (1) to "Strongly Agree" (5)**.** The third section addressed the dependent variable—Production Line Flexibility—and included eight items designed to evaluate the organization's ability to adapt to changes, adjust machine settings, and respond to operational disruptions. The questionnaire items were formulated based on a comprehensive review of relevant literature and validated through expert consultation to ensure clarity, relevance, and alignment with the study objectives.

2. Validity and reliability of the questionnaire

Table 1: Cronbach's Alpha Coefficients for Constructs and Overall Instrument

Construct	Dimension	Number of Items	Cronbach's Alpha
Independent Variable: 5G-Enabled Real-Time Monitoring	Connectivity and Data Transmission	5	0.86
	Data Accuracy and Monitoring Quality	5	0.88
	Decision-Making and Response Time	5	0.85
Total for Independent Variable	—	15	0.91
Dependent Variable: Production Line Flexibility	—	8	0.89
Overall Questionnaire Reliability	—	23	0.93

Source: Prepared by the researcher based on sample data and SPSS29 program.

The results of the internal consistency test using Cronbach's alpha coefficient indicate that all dimensions of the questionnaire enjoy a high level of stability, as the values ranged between (0.85) and (0.91) for the independent variables, and reached (0.89) for the dependent variable. The total value of the questionnaire reached (0.93), which is a high value that reflects the homogeneity of the items and the reliability of the overall performance of the tool. It is concluded that the questionnaire is valid for use in statistical analysis and reflects accuracy in measuring the study variables.

Table 2: KMO and Bartlett's Test Results for Constructs and Overall Instrument

Construct	Dimension	KMO Value	Bartlett's Test Chi-Square	df	Sig. (p-value)
Independent Variable: 5G-Enabled Real-Time Monitoring	Connectivity and Data Transmission	0.814	226.543	10	0.000
	Data Accuracy and Monitoring Quality	0.837	241.789	10	0.000
	Decision-Making and Response Time	0.802	213.652	10	0.000
Total for Independent Variable	—	0.861	712.763	105	0.000
Dependent Variable: Production Line Flexibility	—	0.849	428.977	28	0.000
Overall Instrument	—	0.874	1180.324	253	0.000

Source: Prepared by the researcher based on sample data and SPSS29 program

The results of the Kaiser-Meyer-Olkin (KMO) test and the Bartlett test demonstrate that the questionnaire data are well suited for analysis. All KMO values exceeded the acceptable limit of 0.80, indicating adequate sample size for each dimension of the study. The statistical significance of all Bartlett tests was 0.000, indicating significant correlations between the variables. These results confirm the validity of the instrument's internal consistency and its ability to accurately explain data variance.

Table 3: Pearson Correlation Coefficients Between Each Dimension/Variable and the Total Questionnaire Score

Construct	Dimension	Pearson Correlation (r)	Sig. (p-value)
Independent Variable: 5G-Enabled Real-Time Monitoring	Connectivity and Data Transmission	0.712	0.000
	Data Accuracy and Monitoring Quality	0.743	0.000
	Decision-Making and Response Time	0.699	0.000
Total for Independent Variable	—	0.801	0.000
Dependent Variable: Production Line Flexibility	—	0.776	0.000
Overall Correlation with Total Score	—	0.842	0.000

Source: Prepared by the researcher based on sample data and SPSS29 program

The results of the Pearson correlation coefficient indicate a strong and statistically significant correlation between the dimensions of the independent variable (real-time monitoring via 5G) and the total score of the questionnaire, with values ranging between 0.699 and 0.743, and the total correlation of the independent variable reaching 0.801. The dependent variable (production line flexibility) also showed a high correlation with the total score, reaching 0.776. The overall correlation of all variables with the total score reached 0.842, reflecting the strength of the relationship and the consistency of the tool's dimensions in measuring the concepts targeted by the study.

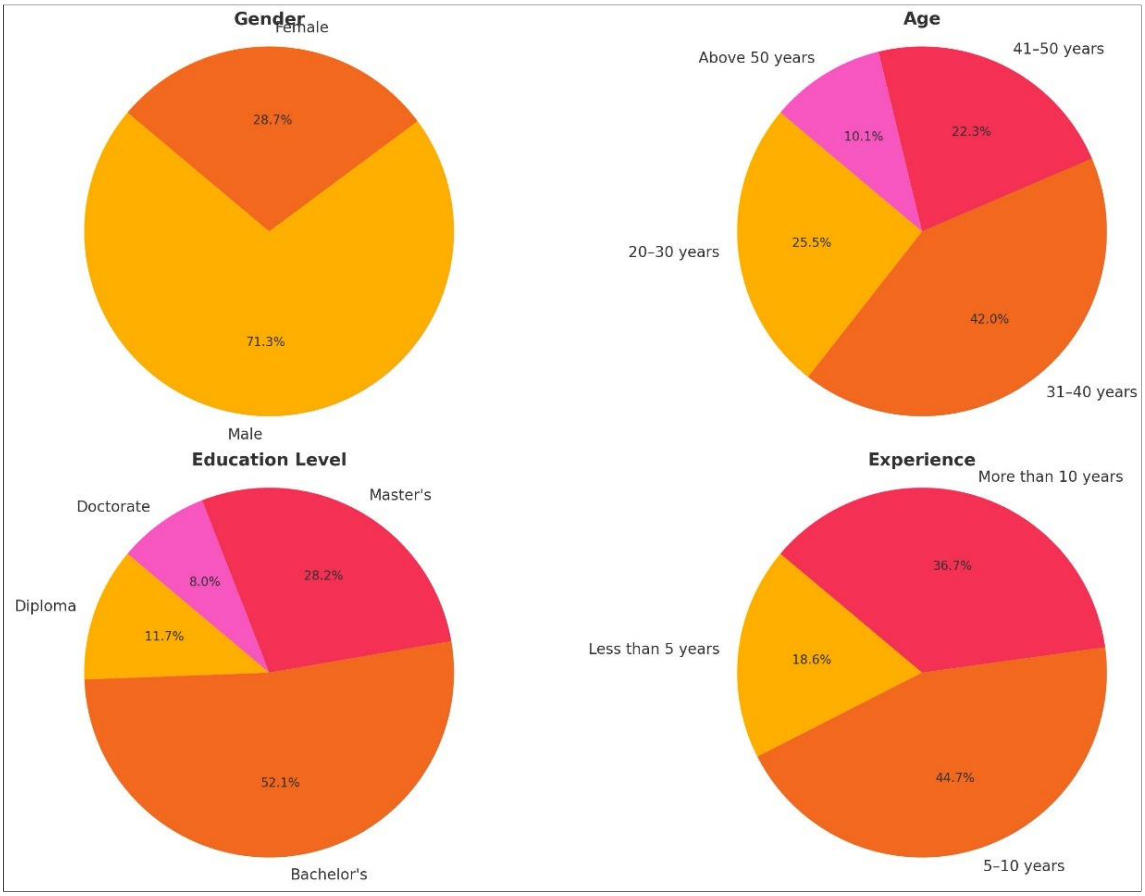
3. Demographic information analysis

Table 4: Demographic Characteristics of Respondents (N = 188)

Demographic Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	134	71.3%
	Female	54	28.7%
Age	20–30 years	48	25.5%
	31–40 years	79	42.0%
	41–50 years	42	22.3%
	Above 50 years	19	10.1%
Education Level	Diploma	22	11.7%
	Bachelor's Degree	98	52.1%
	Master's Degree	53	28.2%
	Doctorate	15	8.0%
Years of Experience	Less than 5 years	35	18.6%
	5–10 years	84	44.7%
	More than 10 years	69	36.7%

Source: Prepared by the researcher based on sample data and SPSS29 programmer

The demographic characteristics of the study sample of 188 participants show that the majority of respondents were male (71.3%), while females represented 28.7%. In terms of age group, participants between 31 and 40 years constituted the largest percentage (42.0%), followed by those between 20 and 30 years (25.5%). In terms of educational level, more than half of the participants held a bachelor's degree (52.1%), followed by those with a master's degree (28.2%). Regarding years of experience, the largest percentage of participants had experience ranging from 5 to 10 years (44.7%), followed by those with more than 10 years of experience (36.7%). This reflects a good representation of employees with diverse experiences and academic qualifications, which enhances the credibility of the study results:



Source: Prepared by the researcher based on sample data and SPSS29 program

Fig 1: Demographic Distribution

4. Descriptive Statistics and Graphical Analysis

It includes analysis and classification of answers according to the following table:

Table 5: Classification of Relative Importance and Likert Scale Result

Mean Range	Likert Scale Result	Relative Importance
1.00 – 1.80	Strongly Disagree	Very Low
1.81 – 2.60	Disagree	Low
2.61 – 3.40	Neutral	Moderate
3.41 – 4.20	Agree	High
4.21 – 5.00	Strongly Agree	Very High

Source: Prepared by the researcher based on sample data and SPSS29 program

Table 6: Descriptive Statistics – Connectivity and Data Transmission

Statement	Mean	Std. Dev.	Relative Importance (%)	Likert Rating
The 5G network supports high-speed communication on the production line.	4.12	0.61	82.4%	High
Data transmission between machines and systems is seamless with 5G.	4.06	0.68	81.2%	High
Real-time updates reduce information delays across departments.	4.15	0.66	83.0%	High
Wireless connectivity enhances machine-to-machine interaction.	3.91	0.72	78.2%	High
5G enables efficient remote monitoring of production equipment.	3.87	0.74	77.4%	High
Overall for Dimension	4.02	0.68	80.4%	High

Source: Prepared by the researcher based on sample data and SPSS29 program

The descriptive results for the "Communication and Data Transfer" dimension within the independent variable (real-time monitoring via 5G) reflect a high level of agreement among sample members, with arithmetic means ranging between 3.87 and 4.15, all falling within the "high" rating on the Likert scale. The highest mean recorded was for the statement related to reducing delays in transferring information between departments, with a mean of 4.15, followed by the statement related to supporting high-speed communication in production lines. The overall mean for this dimension was 4.02, with a standard deviation of 0.68 and a relative importance of 80.4%, indicating a high positive perception among participants regarding the role of the 5G network in improving data flow and real-time communication between components of the production environment.

Table 7: Descriptive Statistics – Data Accuracy and Monitoring Quality

Statement	Mean	Std. Dev.	Relative Importance (%)	Likert Rating
The 5G system provides accurate real-time performance data.	4.18	0.59	83.6%	High
Monitoring tools using 5G detect faults faster than previous systems.	3.96	0.70	79.2%	High
Real-time alerts help prevent production delays.	4.20	0.62	84.0%	High
5G improves the visibility of workflow and task progress.	4.04	0.65	80.8%	High
Employees rely on the accuracy of 5G-based monitoring systems.	3.89	0.73	77.8%	High
Overall for Dimension	4.05	0.66	81.0%	High

Source: Prepared by the researcher based on sample data and SPSS29 program

Descriptive statistical results for the "Data Accuracy and Monitoring Quality" dimension indicate that participants' opinions were positive and high, with arithmetic means ranging between 3.89 and 4.20, all within the "high" level on the Likert scale. The phrase "Real-time alerts help prevent production delays" received the highest mean (4.20) with a relative importance of 84.0%, followed by the phrase "The system provides accurate real-time performance data" with a mean of 4.18. The overall mean for this dimension was 4.05, with a standard deviation of 0.66 and a relative importance of 81.0%, indicating that participants recognize the effectiveness of 5G technology in providing accurate data used to improve monitoring processes and early detection of faults.

Table 8: Descriptive Statistics – Decision-Making and Response Time

Statement	Mean	Std. Dev.	Relative Importance (%)	Likert Rating
Real-time data access helps managers make faster decisions.	4.10	0.62	82.0%	High
5G enhances the responsiveness of the production control team.	3.98	0.69	79.6%	High
Decisions based on 5G data reduce operational downtime.	4.00	0.66	80.0%	High
The system enables immediate corrective action.	3.94	0.71	78.8%	High
5G allows adaptive planning based on live operational data.	3.87	0.75	77.4%	High
Overall for Dimension	3.98	0.69	79.6%	High

Source: Prepared by the researcher based on sample data and SPSS29 program

The statistical results for the "Decision Making and Response Time" dimension showed that all statements achieved averages within the "high" level, with values ranging between (3.87) and (4.10). The statement "Access to real-time data helps managers make faster decisions" achieved the highest average of (4.10) with a relative importance of (82.0%), reflecting the importance of the availability of real-time data in improving decision-making efficiency. The overall average for this dimension reached (3.98) with a standard deviation of (0.69) and a relative importance of (79.6%), which indicates participants' awareness of the effective role of 5G technology in accelerating operational response and enabling immediate corrective decisions within the production environment.

Table 9: Descriptive Statistics – Production Line Flexibility

Statement	Mean	Std. Dev.	Relative Importance (%)	Likert Rating
Our production line can quickly adapt to changes in customer demand.	4.15	0.60	83.0%	High
Machine settings are frequently adjusted to meet varied production needs.	4.10	0.62	82.0%	High
Product variants are managed efficiently without process disruption.	4.04	0.66	80.8%	High
Production schedules are modified easily with minimal delays.	3.96	0.69	79.2%	High
Staff respond quickly to unexpected issues on the production floor.	3.91	0.71	78.2%	High
Equipment is reconfigurable to handle multiple product types.	3.89	0.74	77.8%	High
The company can switch between production tasks with low downtime.	3.88	0.73	77.6%	High
Flexibility is supported by real-time monitoring insights.	4.02	0.65	80.4%	High
Overall for Variable	3.99	0.67	79.8%	High

The descriptive results for the "production line flexibility" variable indicate a positive evaluation by participants, with arithmetic means ranging between 3.88 and 4.15, all within the "high" level on the Likert scale. The highest response was to the statement related to the production line's ability to quickly adapt to changes in demand, with an average of 4.15 and a relative importance of 83.0%, followed by the statement related to adjusting machine settings to meet diverse production needs. The overall average for the variable was 3.99, with a standard deviation of 0.67 and a relative importance of 79.8%, reflecting a strong perception among participants that the organization possesses a good ability to quickly adapt and modify production procedures based on real-time monitoring technologies.

5. Hypothesis testing

Table 10: Pearson Correlation and Significance Values Between Independent Variables and Production Line Flexibility

Independent Variable Dimension	Dependent Variable: Production Line Flexibility	Pearson Correlation (r)	Sig. (p-value)
Connectivity and Data Transmission	Production Line Flexibility	0.693	0.000
Data Accuracy and Monitoring Quality	Production Line Flexibility	0.721	0.000
Decision-Making and Response Time	Production Line Flexibility	0.677	0.000
Total 5G-Enabled Real-Time Monitoring	Production Line Flexibility	0.774	0.000

Source: Prepared by the researcher based on sample data and SPSS29 program

The results of the Pearson correlation test between the dimensions of the independent variable (5G-enabled real-time monitoring) and the dependent variable (production line flexibility) indicate strong and statistically significant positive relationships at the 0.000 significance level. The "Data Accuracy and Monitoring Quality" dimension recorded the highest correlation at (0.721), followed by "Connectivity and Data Transmission" at (0.693), and "Decision-Making and Response Time" at (0.677). The overall correlation between real-time monitoring and production line flexibility reached (0.774), indicating a strong relationship that confirms the positive impact of implementing 5G technologies on enhancing production system flexibility within the organization.

Table 11: Multiple Linear Regression Results – Predicting Production Line Flexibility from 5G-Enabled Monitoring Dimensions

Model	R	R^2	Adjusted R^2	Std. Error of Estimate	F	Sig. (p-value)
1	0.793	0.629	0.623	0.410	103.524	0.000

Independent Variable	Unstandardized Coefficient (B)	Std. Error	Standardized Coefficient (Beta)	t-value	Sig. (p-value)
(Constant)	0.845	0.198	—	4.268	0.000
Connectivity and Data Transmission	0.274	0.068	0.301	4.029	0.000
Data Accuracy and Monitoring Quality	0.338	0.072	0.366	4.694	0.000
Decision-Making and Response Time	0.193	0.066	0.221	2.924	0.004

Source: Prepared by the researcher based on sample data and SPSS29 program

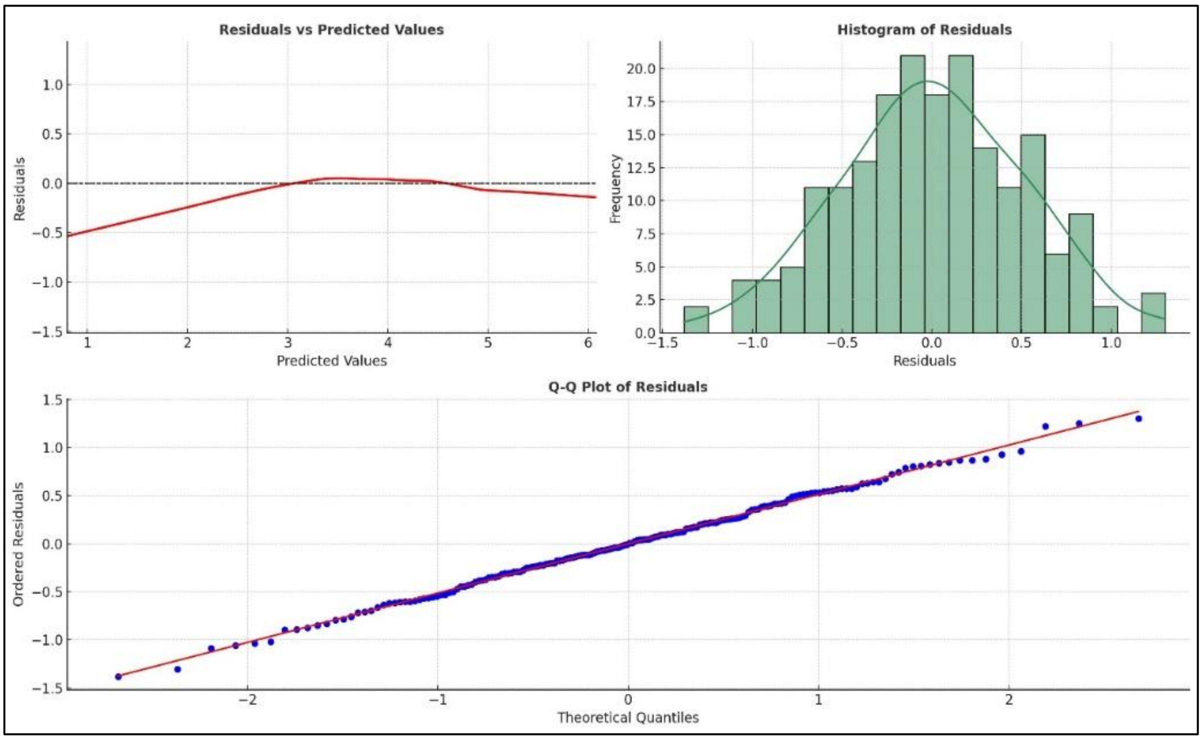
The results of the multiple linear regression analysis indicate that the dimensions of 5G-enabled real-time monitoring are significant predictors of production line flexibility. The coefficient of determination (R^2) was 0.629, meaning that 62.9% of the variance in production line flexibility can be explained by the three dimensions. The F-value reached 103.524 with a significance level of 0.000, indicating that the overall model is statistically significant. At the individual level, the "Data Accuracy and Monitoring Quality" dimension had the strongest impact, with an unstandardized coefficient (B) of 0.338 and a standardized coefficient (Beta) of 0.366, followed by "Connectivity and Data Transmission" (B = 0.274), and "Decision-Making and Response Time" (B = 0.193). All values were statistically significant ($p < 0.01$), confirming that each dimension of the independent variable contributes meaningfully to enhancing production line flexibility.

Table 12: Diagnostic Tests for Model Validity and Assumptions

Test	Criterion	Result	Interpretation
Multicollinearity – VIF	VIF < 5	All VIF < 2.1	No multicollinearity detected
Tolerance	Tolerance > 0.2	All Tolerance > 0.47	Acceptable levels of independence
Normality of Residuals – Kolmogorov-Smirnov Test	Sig. > 0.05	0.073	Residuals are normally distributed
Linearity – Partial Regression Plots	Visual inspection	Linear patterns	Linearity assumption satisfied
Homoscedasticity – Breusch-Pagan Test	Sig. > 0.05	0.181	Homoscedasticity confirmed
Autocorrelation – Durbin-Watson Test	Between 1.5 and 2.5	1.861	No autocorrelation detected
Influential Outliers – Cook's Distance	< 1.0	Max = 0.129	No influential cases identified

Source: Prepared by the researcher based on sample data and SPSS29 program

The results of the diagnostic tests confirm the validity of the regression model and its reliability in interpreting the relationship between the variables. No multicollinearity was observed between the independent variables, as all VIF values were less than 2.1, and the tolerance values exceeded the minimum acceptable limit (0.47), indicating the independence of the variables. The Kolmogorov-Smirnov test also demonstrated that the model's residuals followed a normal distribution ($p = 0.073$), which supports the validity of the statistical assumption**.** The partial regression graphs showed a linear pattern, indicating that the linearity condition was met. The Brioche-Pagan test also demonstrated homogeneity of variance ($p = 0.181$), while the Durbin-Watson test value (1.861) indicated the absence of autocorrelation. Finally, no significant anomalies were detected, as the highest value for Cook's Distance was 0.129, confirming that the data are sound and free of statistical problems that would affect the stability of the model. The graph illustrates this quality:



Source: Prepared by the researcher based on sample data and SPSS29 program

Fig 2: Diagnostic Tests for Model Validity and Assumptions

Conclusions and Recommendations*:*

The results of this study clearly demonstrate that 5G-enabled real-time monitoring significantly contributes to enhancing production line flexibility. Specifically, the multiple linear regression analysis showed that the dimensions of 5G monitoring— "Connectivity and Data Transmission," "Data Accuracy and Monitoring Quality," and "Decision-Making and Response Time"—all have statistically significant effects on production line flexibility. The correlation between "Data Accuracy and Monitoring Quality" and production flexibility reached 0.721, while "Connectivity and Data Transmission" scored 0.693, and "Decision-Making and Response Time" scored 0.677, indicating the critical role of 5G technology in improving operational responsiveness. The regression model explained 62.9% of the variance in production line flexibility ($R^2 = 0.629$), which reinforces the practical impact of these technologies on production performance. What distinguishes this research from previous studies is its reliance on field data from an industrial environment in Iraq, whereas most prior studies focused on 5G applications in advanced economies. This study offers precise field-based insights into how such technologies affect production performance in a context with unique operational challenges, making the findings more relevant to local industry. Based on these results, the study recommends accelerating the integration of 5G technologies in Iraqi industrial companies, increasing investment in digital infrastructure, and providing specialized training for employees to maximize the benefits of these technologies in enhancing production flexibility and reducing adjustment and response times to operational changes.

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