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Sensor Technology to Enhance Employee Engagement and Company's Operational Efficiency

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Employee engagement and a company's operational efficiency are essential for sustainable company growth. We explored how to apply sensor technology to industries to encourage employee engagement and a company's operational efficiency. We created and distributed a questionnaire to 140 employees in different industries and analyzed the data. As a result, we found that sensor technology application had a limited effect on operational efficiency but was closely correlated with employee engagement. As sensor technology is beneficial to foster employee engagement, elaborate training programs and robust data management practices are required to enhance a company's operational efficiency.

1. Introduction

Advanced sensor technology has affected the operation of companies as it is widely used to enhance the efficiency and precision of manufacturing. Sensors are used to detect and measure the degree of various responses to physical stimulation, including movements, body temperature, and heart rate, as well as environmental parameters, including temperature, pressure, and ambient light.(1) Different industries employ sensor technology for manufacturing, logistics, healthcare, and so on. Sensors in manufacturing are used to monitor equipment performance, detect anomalies, and verify product quality. Real-time tracking of products and optimizing supply chain operations in logistics are performed by using various sensors. Using sensor data, companies can comply with the regulatory standards of audits and certification. Without sensors and the data they collect, a company cannot undergo digital transformation, which is essential for innovation and informed decision-making.

Sensor technology has also changed how companies assess the quality of employees' performance. While traditional methods rely on periodic inspection and manual data collection, which is time-consuming and prone to errors (Fig. 1),(2) sensor technology enables automated data collection and data analysis to monitor and solve problems immediately.(3) For instance,

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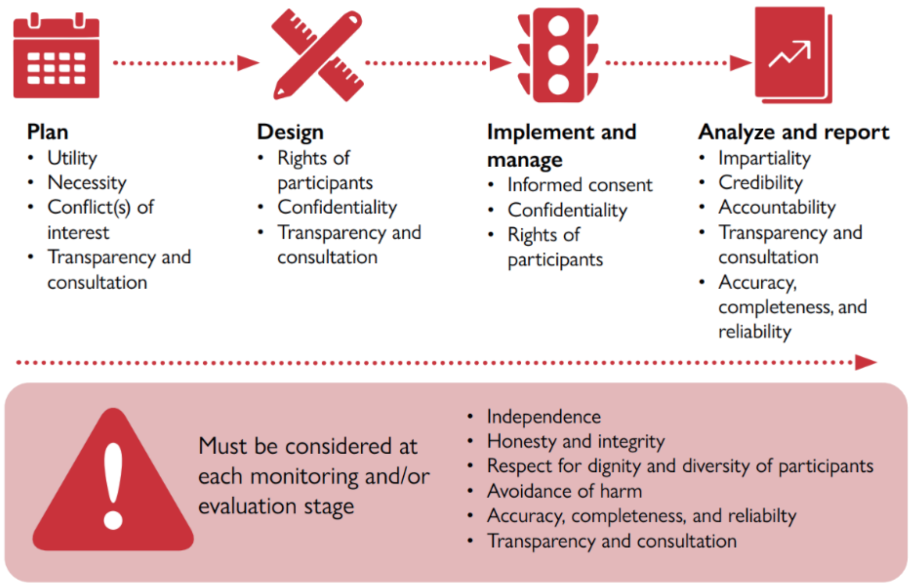

Fig. 1. (Color online) Traditional data collection in assessing employees' performance quality.

environmental sensors used in food production facilities are used to continuously monitor temperature and humidity to guarantee product safety and quality. Warehouse motion sensors are employed to track employees' movement to develop efficient workflows. Such applications show how sensors help transform management practice and enable the dynamic, accurate, and responsive operation of the company.

However, there are challenges for companies to adopt advanced sensor technology, including significant investment in infrastructure, system integration, and training programs for users. Companies need to establish robust data management systems to address privacy and security concerns throughout data collection, processing, and storage. Nevertheless, the advantages of utilizing sensor technology outweigh such challenges, enabling companies to strengthen their operational capabilities and secure competitive advantages.

A real-time evaluation system of employee engagement and operational efficiency needs to be equipped with advanced sensors.[4] The system generally includes state-of-the-art technologies, including the Internet of Things (IoT), artificial intelligence (AI), and machine learning (ML) to process massive amounts of data effectively. Sensors in IoT communicate with each other and connect to the company system for seamless data flow and analysis between different departments or teams in a company.[5] For example, an IoT-connected vibration sensor is used to alert any abnormality in a production line, which is shared by a maintenance team to identify the causes and fix the problems. Advanced sensor technology integrates ML algorithms to predict equipment failure in advance. By using the function of such technology, a company can minimize its downtime while maximizing its operating time as failures are predicted and prevented. Also, miniaturized sensors can be embedded in tiny devices used for various purposes. Such sensor technology advancement helps companies enhance their operational efficiency considerably in an integrated AIoT system (Fig. 2).

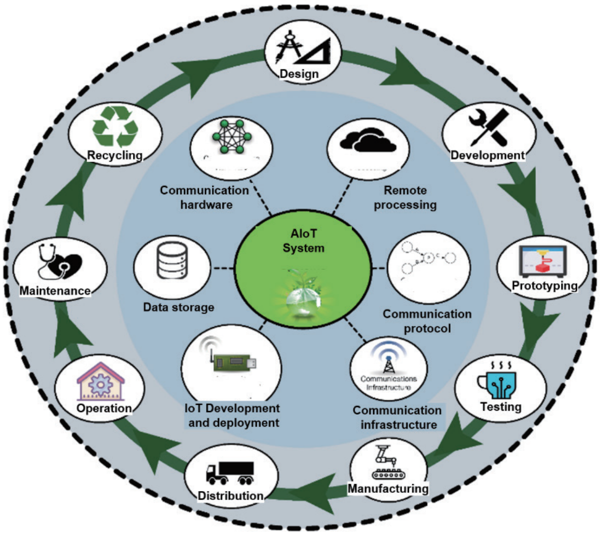

Fig. 2. (Color online) Application of sensor technology in each compartment integrated with SI, IoT, and ML.

Despite the potential of sensor technology to enhance a company's operational quality, its implementation is sometimes hindered because of technical challenges, financial constraints, and resistance from employees or management teams. Additionally, there is a lack of a framework for strategic integration. Therefore, it is necessary to identify key metrics for evaluating operational quality using advanced sensors in the company. It is also essential to assess operational decision-making processes and employee engagement levels by analyzing real-time sensor data. To address potential challenges, a strategic framework is required for implementing the sensor-based evaluation system.

In this study, we explored how to use sensor technology to boost company operations and employee engagement in manufacturing, logistics, health care, and retail industries. From the technical aspects (sensor types and data) and company aspects (employee engagement and support structure), the study results provide a reference on how to adopt and optimize the use of sensor technology for company management.

2. Sensor Technology Application in Workplaces

2.1 Influence of sensor technology

Sensor technology has changed companies' processes as it enables real-time feedback. Companies can solve quality issues proactively by monitoring equipment conditions and product specifications. Any anomalies can be detected and fixed promptly, which improves product quality and decreases workload, defect-related waste, and operating costs. Companies employing advanced sensor technology have acquired a higher level of industry standards.[6] Sensor technology allows employees to control their work processes based on data on the real-time performance and quality of their outputs. For example, sensors used in logistics monitor the condition of merchandise during delivery and track shipments to provide customers with accurate information. As a result, logistics companies can ensure product quality, obtain customer trust, maintain a sound supply chain, and make informed decisions, all contributing to enhanced overall performance.(7)

Moreover, the implementation of sensor technologies increases operational efficiency based on data-driven information.(8) Sensor data are used to analyze trends and patterns for strategic choices of resource allocation and process optimization. Sensor-data-driven predictive analytics are used to predict the possible failure of equipment, thereby enabling timely maintenance. Sensor technology enhances a company's operational efficiency, providing information on how to secure its competitive position in the market.(9)

2.2 Example of sensor usage

In food processing, companies use temperature and humidity sensors to monitor the condition of storing perishable products. A large-scale food distributor owns a huge sensor network across its distribution centers. Continuous monitoring of environmental parameters leads to more than a 20% reduction in spoilage rates and, consequently, improves product quality and the goodwill of customers.(10) Automotive part manufacturers use vibration sensors in their production lines to monitor the performance of the machinery and predict potential failures. Sensor data enables a 30% reduction in downtime caused by equipment failures.(6) In the healthcare industry, sensors in wearable devices are used to monitor vital signs and physiological parameters (heart rate, arterial oxygen saturation, blood pressure, and pulse oximetry level).(11) Proactive monitoring of the parameters enables healthcare providers to react promptly to any problems, thus improving patient health and safety.(7) These examples highlight the value of sensor technology in improving employee engagement and a company's operational efficiency.

2.3 Effect on employee engagement

Employee engagement is essential for a company's operational efficiency, and it can be enhanced by using sensor technology.(12) Enhancing employee engagement can boost a company's sales and improve customer satisfaction by utilizing real-time feedback from sensors. On a construction site, ambient light and temperature are monitored using sensors to provide a safer and more personalized work environment, which increases workers' satisfaction. Using sensor technology creates transparency and collaboration in the workplace as employees actively monitor and assess their performance for continuous improvement. Team support is also encouraged as absenteeism is reduced and retention rates are increased.(13) Moreover, employees can exchange feedback on a sensor-driven platform to engage more in their tasks. Workplace productivity is increased when using smart sensor technology. For example, IoT devices are used to monitor employee movements and optimize workflows on the basis of real-time data analytics. With sensor technology, operations are streamlined by minimizing distractions and inefficient operations.(14) Employee health and well-being are also important metrics measured by sensors. Healthier workspaces can be provided by monitoring environmental parameters, including air quality, noise levels, and lighting. Employees in such a controlled environment feel comfortable working.[15] Companies need to proactively monitor these metrics through sensor-powered technology to prevent health concerns from becoming more serious.

Customer satisfaction is closely related to employee engagement. Engaged employees provide better service and have better customer interactions. High employee engagement leads to higher customer loyalty and customer experience.[12] Sensor technology contributes to the increase in employee engagement as it helps enhance working conditions. Greater employee engagement leads to improved customer satisfaction.

2.4 Effect on company operations

Sensor technology plays an important role in the companies' operations, as real-time data collection and analysis are critical for effective operation. For instance, environmental and equipment maintenance data are important to sustain high-quality standards in their operations.[11] Real-time data collection and analysis allow companies to make informed decisions and ensure high-quality products and high operational efficiency.

Technological progress in data analytics contributes to improving the quality of company operations. The IoT technology has evolved company operations by simplifying device interconnections and data exchange between devices. It enables the continuity, visibility, and control of the supply chain and operation processes.[6] In manufacturing, IoT sensors detect anomalies that minimize downtime and enhance product quality and customer satisfaction. ML algorithms process huge amounts of sensor data and identify patterns and trends autonomously, which enhances quality assessment and predictive maintenance for optimal performance.[14] Companies can optimize operational efficiency that matches or exceeds the required quality standard with such technological progress.

The Department of Energy of the United States highlighted how advanced sensor technology reduced defective rates and enabled higher compliance with industry regulations. The report underscored the importance of technology in quality operational practices. Companies that used data analytics with sensor technologies showed superior decision-making capability. They could predict defect occurrence and determine their causes, thereby increasing productivity significantly.[12] Such a sensor-data-driven approach facilitates continuous improvement in company operations with employees' contributions for real-time data generation.

3. Materials and Methods

We collected data through a questionnaire survey to examine the effects of using sensor technology on employee engagement and a company's operational efficiency. A structured questionnaire was created and distributed to randomly selected respondents from different companies. We compared the results of this study with those of previous studies to validate the results.

3.1 Respondents

Respondents in this study were selected using a purposive sampling method from medium-sized manufacturing companies in China with 100–300 employees. The companies had integrated IoT-connected sensors for industrial automation. The respondents included employees, managers, and quality assurance personnel who had experienced sensor technology and its applications to measure employee engagement and the company's operational efficiency.(16) The respondents were involved in different tasks in manufacturing. We selected 140 respondents as the focused population with experience in manufacturing and using sensors in their tasks, and we assumed that their responses were homogeneous because they had jobs in the manufacturing industry. As this study was exploratory research, 140 was considered sufficient.(17)

3.2 Data collection

A self-administered questionnaire was used to collect data. Close-ended questions were created to assess the respondents' experiences with sensor technology. To increase the response rate and reduce biases, we also interviewed the respondents.(18) The questionnaire was divided into sections on employee engagement levels, perceptions of sensor technology's effectiveness, and satisfaction with the evaluation process. Each question was thoughtfully crafted with clarity and relevance for respondents to provide accurate information based on their experiences. A quantitative scale was used for quantitative data analysis. The questionnaire was distributed to the respondents through email or an online platform. Reminders were sent to the respondents multiple times to maximize the response rate.

3.3 Data analysis

Statistical Package for Social Sciences (SPSS) software was used for data analysis. Descriptive statistics were summarized to understand respondent demographics and variables regarding the application of sensors. An inferential statistical test was adopted to explore the relationship between variables. Differences between groups with different demographic variables and affiliations were also examined using the analysis of variance (ANOVA). Regression analysis was used to investigate the relationship between variables.

3.4 Ethical considerations

Ethical considerations were paramount in this study to protect the respondents' privacy and ensure ethical data collection. The study plan was approved by the institutional review boards and ethics committees of the respondents' companies. The respondents provided informed consent before the questionnaire survey on the confidentiality and use of their responses in this study. No personal information was retained after this study, and all data were anonymized before analysis. Unauthorized access or breaches of the respondents' information were not allowed in compliance with industry standards.

4. Results

Table 1 presents the results of the questionnaire survey. Scores on the perception that sensor technology application improved employee engagement and the company's operational efficiency ranged from 2.60 to 5.20, with a mean of 3.9643 and a standard deviation (SD) of 0.52356, indicating a moderate perception. Employee engagement scored from 2.40 to 4.80, with a mean of 3.9171 and an SD of 0.53213, indicating a high level of engagement. The mean score of the company's operational efficiency was 4.0686 with an SD of 0.49211, ranging from 2.60 to 5.00, indicating positive views on it.

The regression model showing the relationships among sensor technology application, employee engagement, and the company's operational efficiency is summarized in Table 2. The model showed a moderate relationship (R = 0.370) between sensor technology and the other variables. Sensor technology contributed to employee engagement by 13.7%. The standard error of the estimate (STE) (0.46046) indicated variability in the company's operational efficiency, which was not explainable by the model. Employee engagement was estimated through a questionnaire survey, which is prone to measurement error, leading to a large STE and variability. As employees' responses are influenced by various factors, such as mood, incidents, or social relationships, it is not easy for the model with employee engagement as a variable to present a consistent relationship.[19] This necessitates further study to objectively estimate employee engagement.

The ANOVA results indicated that the regression model was statistically significant ($df = 2$; $F = 10.882$; $p < 0.001$). The regression sum of squares (4.614) is the variance that the model explains, and the residual sum of squares (29.047) is the unexplained variance. The mean square for regression was 2.307, and the residual was 0.212 (Table 3). The company's predicted operational efficiency with employee engagement and sensor technology application was zero with a constant ($B = 2.738$). Employee engagement turned out to be a significant predictor of the company's operational efficiency ($B = 0.345$, $p < 0.001$), suggesting that more employee engagement is necessary to enhance the company's operational efficiency. However, sensor technology application impacted the company's operational efficiency less significantly than employee engagement ($B = -0.006$, $p = 0.950$) (Table 4).

Table 1
Descriptive statistics of questionnaire survey results.

Variable	*N*	Lowest score	Highest score	Mean score	*SD*
Sensor technology application	140	2.60	5.20	3.9643	0.52356
Employee engagement	140	2.40	4.80	3.9171	0.53213
Company's operational efficiency	140	2.60	5.00	4.0686	0.49211
Valid response number (listwise)	140				

Table 2
Model summary statistics for multiple regression predicting operational efficiency.

Model number	R	R^2	Adjusted R^2	STE of estimate
1	0.370	0.137	0.124	0.46046

Predictors: (Constant), employee engagement, sensor technology.

Table 3
ANOVA results.

Model number	Term	Sum of squares	Degree of freedom	Mean square	*F*	Significance level
1	Regression	4.614	2	2.307	10.882	0.000[b]
	Residual	29.047	137	0.212		
	Total	33.662	139			

Dependent variable: company's operational efficiency.

Table 4
Coefficients of regression model.

Model number	Term	Unstandardized coefficients		Standardized coefficients	*t*	Significance level
		B	STE	*β*		
1	(Constant)	2.738	0.334		8.190	.000
	Sensor technology application	−0.006	0.089	−0.006	−0.063	0.950
	Employee Engagement	0.345	0.087	0.373	3.948	.000

Dependent variable: company's operational efficiency.

Pearson correlation coefficients were calculated to explore relationships among sensor technology application, employee engagement, and the company's operational efficiency. Sensor technology application was strongly positively correlated to employee engagement (r = 0.544, $p < 0.001$) as the respondents demonstrated a strong positive perception of sensor technology. There was a moderate positive correlation between employee engagement and the company's operational efficiency (r = 0.370, $p < 0.001$). The correlation between sensor technology application and the company's operational efficiency (r = 0.197, p = 0.020) was not higher than that between employee engagement and sensor application usage (Table 5).

5. Discussion

5.1 Effects of sensor technology on employee engagement and operational efficiency

To enhance the company's operational efficiency, employee engagement is essential. Real-time sensor data allows companies to detect quality problems in production and swiftly correct the corresponding process to maintain quality standards.[6,9] The results of this study align with previous results as constant monitoring and data-supported decision-making enhance the company's operational efficiency. However, the results of this study revealed a weak relationship between sensor technology application and the company's operational efficiency. Such a weak relationship can be caused by a lack of training for the new technology adoption, efficient workflow and operational processes, and the company's supportive culture.[20] Therefore, companies need to create a mechanism to assess their operations, products, and services, continuously improve their working environment, and enhance employee engagement by integrating advanced sensor technology.[14]

Table 5
Pearson correlation coefficients among sensor technology application, employee engagement, and company's operational efficiency.

Variable	Statistics	Sensor technology	Employee engagement	Company's operational efficiency
Sensor technology application	Correlation coefficient	1	0.544**	0.197*
	Significance (2-tailed)		0.000	0.020
	N	140	140	140
Employee engagement	Correlation coefficient	0.544**	1	0.370**
	Significance (2-tailed)	0.000		0.000
	N	140	140	140
Company's operational efficiency	Correlation coefficient	0.197*	0.370**	1
	Significance (2-tailed)	0.020	0.000	
	N	140	140	140

*Correlation is significant at $p = 0.05$ (2-tailed). **Correlation is significant at $p = 0.01$ (2-tailed).

A positive correlation between the company's operational efficiency and employee engagement was observed, and the critical role of real-time sensor data in making informed decision-making was verified. Real-time data analytics enables decision-making based on factual data by eliminating decision-making based on intuition or experience.[21] In complex manufacturing processes, timely interventions and enhanced employee engagement using sensor technology are mandated to increase productivity. Real-time data and information improve the operational efficiency of the company and enhance employee satisfaction, which increases employee engagement.[19] Companies need to use predictive measures based on real-time sensor data to minimize equipment failure and downtime effectively. Real-time data analysis benefits companies and represents the promising potential of using sensor technology. To effectively integrate sensor technology into the company's operations, appropriate strategies are required. Sensor technology needs to be used in line with a company's goals, with an effective and well-structured implementation strategy. Robust employee training programs are crucial for the strategic implementation of sensor technology and the seamless exchange of sensor data among stakeholders.

Challenges in collecting and utilizing data must be addressed. Companies need to invest more in robust data analytics to process huge volumes of sensor data efficiently without compromising data security and privacy. We used a questionnaire survey to explore the effect of sensor technology application on employee engagement and operational efficiency; however, more objective methods should be adopted to obtain behavioral data (e.g., log-in times, communication patterns, and time spent on tasks), performance metrics, and physiological monitoring metrics, and to reduce the variability of the related regression model.[20] Wearable devices can be used to collect such data to measure employee engagement and operational efficiency. Along with such data collection, companies must adopt real-time data analytics to enhance their operations and become competitive owing to their timely decisions based on information obtained by sensor networks.[19] To encourage employee engagement, effective training programs and fair evaluation systems are also essential.

Table 6
Differences between traditional and sensor-based operational methods.

Measures	Traditional methods	Sensor-based methods
Measurement method	Manual measurement using tools (e.g., goniometers)	Automated data collection via sensors
Accuracy	Subject to human error	High accuracy with objective data
Efficiency	Time-consuming; requires clinicians' presence	Quick data collection; remote monitoring
Employee engagement	Limited interactions; passive involvement	Active participation; self-assessment
Data analysis	Manual interpretation of results	Real-time data analysis and feedback

5.2 Traditional and sensor-based operational methods

Traditional equipment control methods in manufacturing require trained personnel to collect data through manual measurements. These methods are time-consuming and error-prone, producing significantly varying results. In contrast, in the case of sensor-data-based methods, data is collected autonomously to ensure accuracy and real-time feedback. At the same time, sensor-based assessments of equipment operation also ensure reproducibility and continuous monitoring, encouraging employee engagement and self-assessment of employee performance.(19) Sensor-based operations benefit from enhanced accuracy, efficiency, and engagement in the company's processes. Therefore, sensor technology needs to be integrated into the operations of the company. Table 6 summarizes the differences between traditional and sensor-based operational methods.

5.3 Challenges and barriers

Despite the advantages of implementing sensor technology in the company's operations, several barriers to this end exist. The interoperability of sensor networks should be ensured to integrate multiple devices and platforms and minimize the complications in data communication. The lack of standardized protocols for sensor data collection and usage leads to fragmented data utilization and complex data analyses. Data security and privacy concerns should also be ensured. When sensors collect large amounts of data, data breaches are a huge concern for companies. A safeguard is required to protect the data from unauthorized access. Companies must have preventive measures for data breaches to fully utilize sensor-based solutions and prioritize security.

There are also technological limitations in applying sensor technology. The effective use of wearable devices with sensors can be constrained by limited battery life, compact size, and restricted data transmission capabilities. Additionally, physical environments might hinder sensor performance, as obstacles disrupt signal transmission and degrade data quality.

Financial constraints impede the adoption of sensor technology, too, as substantial investment is necessary to implement and maintain advanced sensor networks.(22) A lack of investment hinders the introduction of sensor technology, even if it enables effective company operations.

6. Conclusion

In this study, we investigated the role of sensor technology in enhancing employee engagement and a company's operational efficiency. Sensor technology enables the effective and efficient operation of the company as it leads to an increase in employee engagement. Companies need to encourage employees' active participation in their operations using sensor data. Presently, certain industries are actively introducing sensor technology. Technological maturity enables the proliferation of sensor technology applications in diverse contexts. However, proprietary data collection and analysis are required to provide important information to enhance the workplace environment in which employees perform better, which leads to improved company operational efficiency. However, it is necessary to understand issues in the implementation of sensor technology. To solve related problems, companies should formulate a strategic plan to obtain objective data by adopting wearable sensors, supplementing questionnaire surveys. It is also necessary to secure collected data and sensor networks and offer tailored training programs for employees. Significant investment is necessary to seamlessly integrate and ensure the interoperability of sensor networks in the data management system.

Sensor technology has advanced companies' operations in terms of efficiency and innovation. By addressing challenges such as interoperability, data security, technical impossibility, and a lack of investment, companies benefit from sensor technology in terms of improved operational practices and enhanced operational efficiency and performance.

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