KAPITEL 8 / *CHAPTER 8* [8]
APPLICATION OF REMOTE INDUSTRIAL MONITORING SYSTEMS (RIMS) IN MANUFACTURING

DOI: 10.30890/2709-2313.2024-29-00-015

Introduction

Remote Production Monitoring Systems (RPMS) can vary greatly depending on their functions, scale, and production specifics. However, the relevance of research is driven by the fact that the adoption of Remote Production Monitoring Systems (RPMS) is increasing in the modern competitive business environment. Firstly, rapid technological progress and increasing demands for stability, reliability, and resilience are pushing manufacturers towards implementing more efficient methods of monitoring and managing production processes. Secondly, in the context of ongoing globalization and the expansion of business geography, where companies may have production facilities at significant distances from each other. RPMS become an integral part of remote management and production monitoring. Thirdly, in an environment of constant market competition, product quality and workplace safety emerge as key success factors for companies. Therefore, in the context of modern business, the adoption of RPMS becomes an urgent necessity.

Each manufacturing enterprise has its unique features, processes, and needs. Therefore, it is important to provide a screenshot of the accumulated experience in implementing RPMS in manufacturing to the extent that it allows identifying these features and considering available user solutions in terms of overall utility.

Currently, 70% of successful automotive manufacturers utilize RPMS for monitoring production lines and ensuring automobile quality control. For instance, Tesla has extensively utilized RPMS on its production lines since the 2020s. It includes real-time tracking of production parameters, monitoring product quality, and ensuring timely response to any anomalies or deviations. Toyota Motor Corporation also utilizes RPMS on its production lines to maintain high product quality and optimize production efficiency. BMW Group employs RPMS to ensure high quality and efficiency in

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production, as well as to uphold safety standards.

In industrial manufacturing, up to 80% of leading manufacturers use RPMS to control production parameters. For example, Siemens employs RPMS on its production lines to detect defects and enhance product quality. Meanwhile, Procter & Gamble uses RPMS on its cosmetic product manufacturing lines for quality control and ensuring compliance with safety standards.

In the food production industry, up to 50% of leading manufacturers utilize RPMS for controlling the quality of raw materials and finished products. A notable example is Nestlé, where the manufacturer installs quality monitoring systems in its factories to detect potential issues and ensure compliance with quality standards. Additionally, up to 20% of such manufacturers utilize RPMS for tracking the storage and transportation conditions of products. Among them, Cargill stands out, as they have installed temperature, humidity, and other parameter monitoring systems to ensure proper storage conditions for their products. Over 10% of small and medium-sized productions utilize this system to comply with safety and sanitation standards. For instance, Mondelez International employs RPMS to ensure safety and sanitation standards through monitoring systems on confectionery production lines.

In the energy sector, RPMS are increasingly used to monitor the operation of power plants, transformer substations, and energy grids. Functional RPMS have been deployed on nuclear power plants since the 2000s. Currently, RPMS are also employed in wind farms to monitor the operation of wind turbines, electronic control systems, and power transmission. General Electric (GE) utilizes RPMS to monitor the condition of equipment and operational parameters of wind turbine installations.

8.1. Basic factors that have driven the process of implementing remote production monitoring systems (RPMS) in manufacturing

Given the outlined relevance and increasing utility in research, the specific foundational factors driving the process of implementing remote production

monitoring systems (RPMS) in manufacturing are as follows:

1. RPMS enables the efficient utilization of resources, including technological resources (through real-time equipment monitoring [1]), labor resources (through tracking of working hours, productivity, and employee activity [1]), and material resources (through real-time control of material and raw material consumption [3-4]).
2. RPMS allows for the detection of anomalies in production processes, responding to risks, and optimizing plans and resource utilization to avoid negative consequences such as production accidents, production line stoppages, and product losses;
3. RPMS enables overseeing processes (involving continuous monitoring of various production parameters in real-time [3]), automatic deviation detection (entailing setting up processes for automatically detecting deviations from specified quality standards [2]), data analysis (involving the collection of large amounts of data about production processes [1]), and prompt response to issues (entailing real-time deviation detection [2]).

Thanks to the highlighted capabilities of remote monitoring, manufacturers gain the ability to control and manage production processes even at remote facilities or in different regions, according to the specifics outlined in Figure 1.

Therefore, remote production monitoring systems are not only relevant but also essential for modern manufacturers, considering their pursuit to remain competitive and efficient Therefore, remote production monitoring systems are not only relevant but also essential for modern manufacturers, considering their pursuit to remain competitive and efficient.

Considering the above, the author systematically discusses the features through which RPMS allows for [2-3]:

- Equipment monitoring involves the traditional process of collecting, analyzing, and tracking equipment parameters and status at a production site or facility to ensure the efficiency, safety, and reliability of its operation;

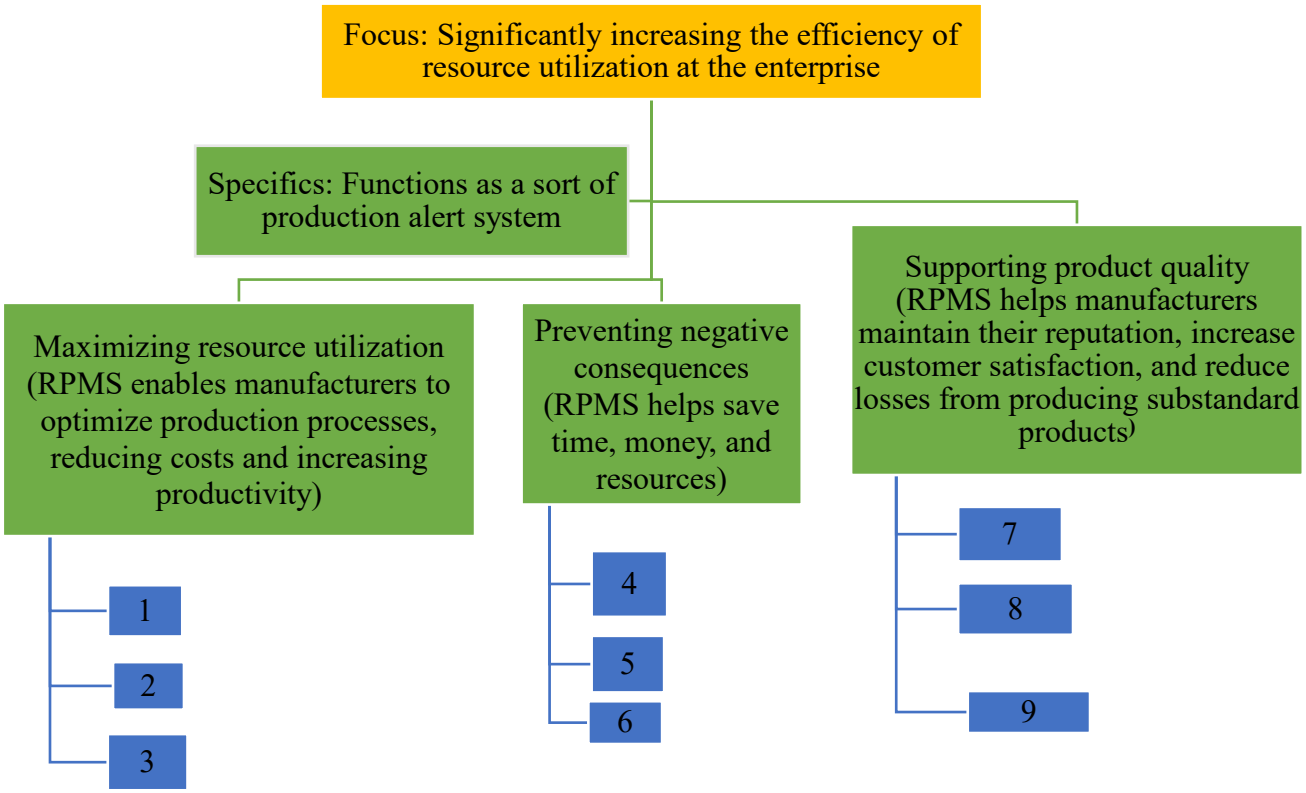

Figure 1 - Specifics of controlling and managing production processes through remote production monitoring systems (RPMS)

Note

(1) It means that production lines can be maximally utilized without unnecessary stops or interruptions; (2) It helps ensure that all opportunities for increasing productivity and optimizing workflow processes are identified; (3) It signifies the absence of over-expenditure and reduction of waste, thereby enhancing production efficiency and lowering costs; (4) It means that RPMS can continuously monitor production processes and detect any anomalies or deviations from the norm; (5) It means that RPMS can develop forecasts regarding potential risk situations, such as production accidents or line stoppages; (6) It means that RPMS can help in planning production more efficiently, taking into account the risks of potential issues arising; (7) It allows manufacturers to track and control work processes with great precision; (8) It enables prompt response to any anomalies or deviations that may affect product quality; (9) It means that data can be analyzed using artificial intelligence algorithms or machine learning to identify patterns or trends indicating potential deviations in product quality.

A source: [2-3]

- Optimization of production processes involve identifying and implementing effective methods and technologies to enhance productivity and resource utilization;

- Reduction of production costs involve processes aimed at decreasing the overall expenses associated with manufacturing products or providing services, with the goal of increasing profitability and competitiveness of the enterprise.;

- Monitoring of employee working conditions involves the processes of collecting, analyzing, and tracking various parameters related to the work environment and working conditions of employees at a production site or office;

- Quality monitoring encompasses the processes of assessing the conformity of products or services to established quality standards.

Note that a remote production monitoring system (RPMS) can be regarded as a kind of production alarm system with additional functions and capabilities that surpass conventional production alarms.

Similar to conventional production alarms that signal the occurrence of a problem or malfunction, RPMS detects anomalies in equipment operation and production processes. However, it emphasized that RPMS not only alerts about issues but also enables the prediction of problem consequences and proactive response to them.

8.2. The functioning of RPMS as a production alarm system

RPMS, when functioning as a production alarm system, operates on a framework of fundamental algorithms integrated into subsystems including equipment monitoring, energy consumption monitoring, product quality monitoring, employee working conditions monitoring, and production process monitoring (see Table 1).

The table provides an overview of some fundamental subsystems of RPMS. However, RPMS can manifest in various combinations and configurations tailored to specific production needs and requirements. However, in any case, to ensure the functioning of RPMS, three types of core algorithms are implemented, among which the following are distinguished [1-2; 4-5]:

- RPMS algorithm for analyzing data on the state of the manufacturer's production system.
- RPMS algorithm for monitoring employee working conditions.
- RPMS algorithm for tracking the parameters of production systems and products.

Table 1 - Integration zones of the core algorithm system, which are integrated into the subsystems of RPMS

Subsystems	Characteristics of subsystems	Actions of the core algorithm system
equipment monitoring subsystems	Aimed at tracking the condition of equipment on production lines	Enable the detection of anomalies, tracking of wear levels, and forecasting of maintenance and repair needs
energy consumption monitoring subsystems	Aimed at monitoring the usage of electricity, gas, water, and other energy resources at the production facility	Enable the identification of energy efficiency and implementation of measures to reduce energy consumption
product quality monitoring subsystems	Focused on tracking the quality of produced goods at various stages of production	Enable the measurement of quality parameters, detection of defects, and analysis of deviations from quality standards
employee working conditions monitoring subsystems	Geared towards monitoring working conditions for employees in production areas, such as noise level, ventilation, temperature, etc.	Enable the identification of potential health and safety hazards for employees
production process monitoring subsystems	Directed at monitoring various parameters of production processes, such as temperature, pressure, humidity, pH level, etc.	Enable the control of production processes and ensure their optimization

A source: [1; 4-5]

As a production monitoring system, RPMS utilizes various sensors, data collection devices, and software for processing this data to analyze information about the state of the manufacturer's production system [1; 2]. Under such conditions, the manufacturer is capable of identifying opportunities for process optimization and cost reduction. RPMS not only detects problems but also offers solutions to improve production efficiency and reduce costs.

The RPMS algorithm for analyzing data on the state of the manufacturer's production system should focus on steps such as data collection, data transmission, data processing, analysis, and output of results (see Figure 2).

Thus, through the defined algorithm, RPMS analyzes data from various sources, processes it, and provides manufacturers with valuable information for making managerial decisions and optimizing production processes.

It is observed that, akin to workplace safety systems, RPMS monitors employees' working conditions, including temperature, humidity, and other factors. Beyond merely

identifying issues in working conditions, it also detects potential hazards and breaches of employee safety.

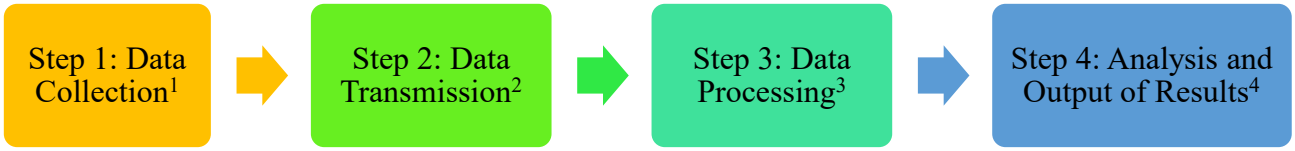

Figure 2 - RPMS algorithm for analyzing data on the state of the manufacturer's production system

Note
1 At this step, the RPMS collects data from various sources, such as sensors on equipment, parameter measurement devices (temperature, pressure, humidity, etc.), energy consumption monitoring systems, as well as from other automated sources like Manufacturing Execution Systems (MES) and Production Process Management Systems.
2 At this step, the collected data is transmitted to the central RPMS system for further processing and analysis. It can occur through wireless networks, cable connections, or cloud platforms.
3 At this step, RPMS utilizes a variety of data processing methods including statistical analysis, machine learning, artificial intelligence algorithms, and others, to detect patterns, anomalies, or deviations from standards.
4 At this stage, the analysis aims to identify patterns, trends, or issues within the production process. The results of the analysis may be presented through reports, graphs, diagrams, or even recommendations to enhance production efficiency.
A source: [1; 3; 6]

The RPMS algorithm for monitoring employee working conditions may include the following steps: data collection on working conditions, data transmission, data analysis and anomaly detection, generation of alerts and recommendations, recording and reporting (see Figure 3).

Thus, through the defined algorithm, RPMS effectively monitors employees' working conditions and contributes to improving their safety and comfort in the workplace [5].

Similar to traditional quality control systems, RPMS tracks the performance parameters of production systems and the output characteristics of products to ensure compliance with quality standards. Due to its outlined specificity, the RPMS is capable of promptly responding to production issues.

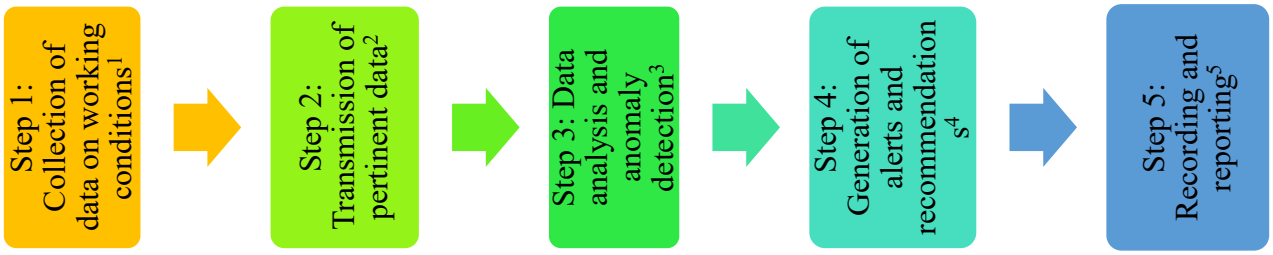

Figure 3 - RPMS aalgorithm for monitoring employee working conditions

Note

1 At this step, RPMS utilizes sensors and devices to measure various parameters of working conditions, such as temperature, humidity, lighting levels, noise levels, and so on

2 At this step, the gathered data is transmitted to the central RPMS system via wireless networks, cable connections, or cloud platforms.

3 At this step, the RPMS analyzes the collected data to detect any anomalies or deviations from the norm that may indicate potential hazards to employees.

4 At this step, if hazardous conditions are identified, the RPMS generates warnings or recommendations for management or employees to prevent danger or enhance safety.

5 At this step, the system may also record and store data on working conditions for further analysis, as well as for maintaining safety reports in the workplace.

A source: [1; 4-5]

The RPMS algorithm for tracking the parameters of production systems and products may include the following steps: data collection on production parameters, data collection on product output characteristics, data transmission to the central system, data analysis and comparison with quality standards, detection of deviations and production issues, automated adjustment of production processes, reporting, and data analysis (see Figure 4).

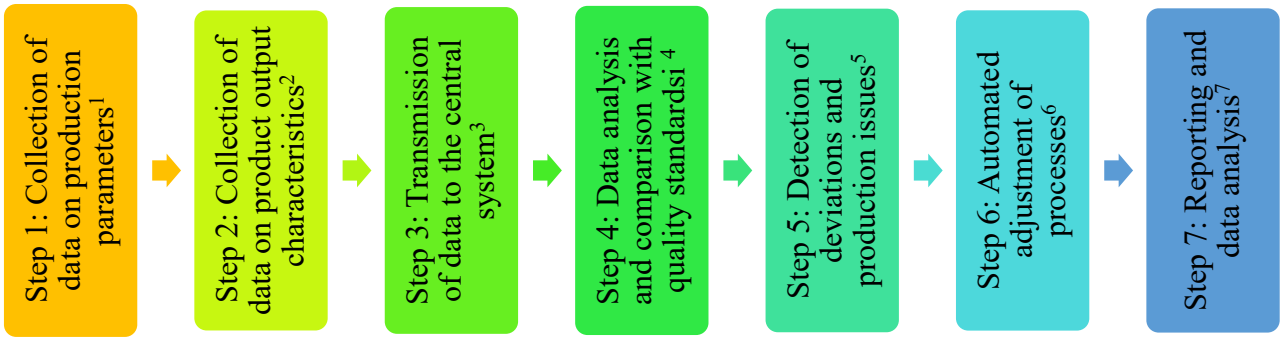

Figure 4 - RPMS algorithm for tracking the parameters of production systems and products

Note

1 At this step, the RPMS collects data on various parameters of production systems, such as temperature, pressure, cycle time, production speed, energy consumption, etc.

2 At this step, the RPMS collects data on the characteristics of the produced products, such as dimensions, weight, quality indicators, raw material consumption, and so forth.

3 At this step, the collected data is transmitted to the central RPMS system for further processing and

analysis.
4 At this step, the RPMS analyzes the collected data and compares it with the quality standards set for the specific product.
5 At this step, if any deviations from quality standards or production issues are detected, the RPMS generates signals or notifications for operators or relevant departments.
6 At this step, RPMS may have the capability for automatic intervention in production processes to correct deviations and ensure compliance with quality standards.
7 At this step, RPMS may store data for further analysis and generate reports on the efficiency of production processes and product quality.

A source: [1; 6-7]

This algorithm empowers RPMS to maintain effective oversight over production parameters and product qualities, guaranteeing adherence to quality benchmarks and swift responsiveness to any production challenges.

8.3. The connection between RPMS systems in production and the stabilization strategy of the industrial and economic enterprise activities

Remote Production Monitoring Systems (RPMS) in manufacturing can serve as tools for implementing a business entity's stability strategy (interpreted as a set of actions aimed at maintaining or maneuvering stability, reliability, and sustainability parameters of operation). As mentioned earlier, RPMS enables manufacturers to gather critical data about production processes, equipment, working conditions, and product quality in real-time, even at remote locations. This information helps businesses:

- Manage the stability, reliability, and resilience of production based on the data collected from production processes and working conditions (see Table 2);

- Forecasting possible risks to stability, reliability, and resilience includes technical issues and equipment failures; deficiencies in the supply chain; lack of qualified personnel; conflicts within the team or loss of key personnel; economic fluctuations; natural disasters; and other factors, such as information threats and cyberattacks (Table 3);

Table 2 - Directions in which it becomes possible to manage the stability, reliability, and resilience of production

Possible directions	Features of outlining the direction	The specificity of influencing stability, reliability, and resilience in production
managing production stability	Implementation of measures to ensure the continuity and consistency of production processes	It includes regular monitoring and control of all aspects of production, such as processes, equipment, technologies, workforce, and resources
production reliability management	Implementation of measures to prevent failures and accidents in the production process	It includes planning for maintenance, equipment servicing, implementing predictive maintenance and failure diagnosis programs, as well as creating contingency action plans for unforeseen situations
production resilience management	Implementation of measures to ensure high levels of durability and resilience of production systems to withstand external influences and stressful situations	It involves analyzing potential threats and risks, developing crisis management plans, as well as implementing measures to enhance the flexibility and adaptability of production systems

A source: [4; 7]

Table 3 - Directions in which it becomes possible to forecast potential risks to stability, reliability, and resilience of activities through RPMS

Possible risks	Features of risks affecting stability, reliability, and resilience of operations	Specificity of impact on the stability, reliability, and resilience of production
Technical issues and equipment failures	Malfunction or failure of key equipment can significantly slow down production processes and lead to production stoppage. Underinvestment in equipment, its obsolescence, or improper usage can be the cause of technical issues	These risks can occur individually or in combination, and their impact on the stability, reliability, and resilience of a company's operations can be significant. Effectively managing these risks requires a systematic approach and the implementation of appropriate measures to minimize the impact of negative factor.
Supply chain deficiencies	Problems with suppliers of raw materials or components can lead to interruptions in production processes or even halt production altogether. Improper inventory management or insufficient planning can exacerbate this risk	
Personnel issues	The absence of qualified personnel, conflicts within the team, or the loss of key personnel can negatively impact productivity and production quality	
Economic fluctuations	Market changes, such as rising raw material prices, currency fluctuations, or a decline in consumer demand, can affect the profitability of the enterprise and its financial stability	
Natural disasters, etc.	Natural disasters, technological accidents, or political instabilities can lead to losses for the enterprise and its production capabilities	
Information threats and cyber attacks	Unauthorized access to confidential information, viral attacks, or cybercrimes can disrupt normal business operations and cause significant financial and reputational losses	

A source: [1-2]

- To avoid negative consequences (ensure maneuvering) in the face of variable disruptions in stability, reliability, and resilience of operations through the utilization of real-time monitoring, emergency warning systems, automated control systems, artificial intelligence, and machine learning (Table 4).

Table 4 - Using RPMS to mitigate negative consequences of disruptions in stability, reliability, and resilience of operations

Maneuvering directions	Navigational maneuvering features	Specifics of impact on the stability, reliability, and resilience of production
Real-time monitoring	Continuous monitoring of production parameters, which allows for promptly detecting any changes or deviations from the norm	Maneuvering enables enterprises to actively manage risks and effectively respond to any changes in the production environment, ensuring stability, reliability, and resilience of operations
Emergency warning systems	Utilizing alerts for potential issues or emergency situations enables prompt response and implementation of necessary measures to prevent negative consequences	
Automated control systems	Implementation of automated control systems capable of reacting to real-time changes and taking necessary measures to restore stability and reliability of production processes	
Artificial intelligence and machine learning	Utilizing artificial intelligence and machine learning algorithms to analyze large volumes of data can help identify complex relationships and patterns that are difficult to detect using traditional methods	

A source: [6-7]

So, based on the communication zones of RPMS in production with the stabilization strategy, as outlined in Figure 5.

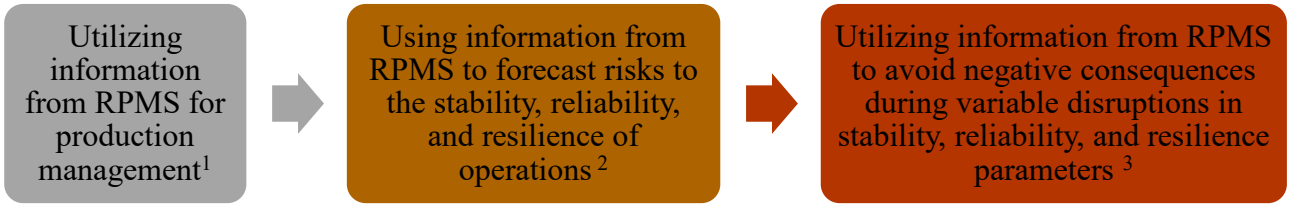

Figure 5 - Communication zones of RPMS in production with a stabilization strategy of the industrial and economic enterprise activities

Note
1 RPMS enables businesses to manage production more efficiently, considering the latest information needs
2 RPMS allows businesses to forecast potential risks that may affect the stability, reliability, and resilience of operations and take appropriate measures to prevent them.
3 RPMS enables businesses to promptly respond to any disruptions in stability, reliability, and resilience of operations to avoid negative consequences.
A source: [2; 3]

Summary and conclusions.

In accordance with the above, the application of RMMS in production is based on the nature of its connection with the stability strategy, focusing on the following directions:

1. Prevention of production accidents. So, RPMS allows for the detection of anomalies in production processes and equipment, which can help prevent accidents and unforeseen production stoppages.
2. Optimization of production processes. RPMS, through data analysis, can identify opportunities for optimization and increased productivity of production and other processes.
3. Improvement of product quality: RPMS allows for tracking product quality parameters in real-time, enabling timely detection of deviations from quality standards and taking measures to rectify them.