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Effects of a Reliability Engineering Department on an Industrial Organization: An Empirical Investigation

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ABSTRACT: In industrial companies, efficient maintenance is a prerequisite for overall competitiveness and, therefore, needs the utmost attention from the highest management level. Maintenance departments work primarily in a preventive and proactive manner in order to detect and avoid damages early instead of reacting to sudden failures. Some companies have gone further and introduced an independent Reliability Engineering Department (RED). This RED is intended to improve equipment dependability and decisively reduce production downtime to an even greater extent. The effects of a RED on industrial organizations have received little academic attention to date. This study aims to address this research gap by analyzing vital questions concerning the advantages of an independent RED. The research has been carried out using an empirical quantitative online survey. The study results demonstrate that many companies have already introduced an independent RED. It is envisioned that many businesses, if not most, currently missing a RED will soon introduce one. Furthermore, it is presented that companies that have already implemented a RED expect recurring significant annual savings. For the most part, these REDs are organizationally integrated into the existing maintenance department. The surveyed companies demonstrate that a RED, virtually without exception, generates a positive contribution to the company.

KEYWORDS: Cost Savings, Strategy, Organization, Key Performance Indicators, Maintenance, Reliability Engineering

Introduction

Having reliable and cost-efficient operable machinery is crucial for every production company (Kiran et al. 2016, 577). Serious malfunctions – sometimes even minor ones – or unexpected breakdowns are unacceptable in modern plants and usually costly (Smith 2011, xix) not just for the repair itself but for the loss of production, which is often much more expensive. A study from Great Britain shows that defective equipment is responsible for three percent of all lost workdays (Williamson 2017), not to mention the loss of reputation if a company cannot deliver on time. A principal managerial task is to implement performance improvements (Hawkes and Spedding 2022, 16; Volkelt 2020, 2). Thus, all managers should be committed to this topic. To keep the equipment in a 24/7 production company permanently productive and in good condition, firms of a specific size usually have a maintenance department. This department can be staffed by the company's own personnel or by personnel from external businesses. Various organizational characteristics and depths are conceivable. They are, in practice, often historically grown. The departments' goals sometimes diverge, as well. Some maintenance organizations are content with correcting errors; others apply preventive measures or try to predict errors before they occur (Strunz 2012, 1-34).

In the past, measures to improve a plant's reliability were usually part of the general maintenance department (Madu 2000, 938-39). In some more prominent companies or facilities, it was part of asset management, which took care of all assets within the company or facility. This department is usually but not consistently an integral part of the maintenance department.

To further improve equipment reliability, maintenance departments are looking for implementable solutions. These can lie in employing more preventive maintenance work (Jin 2019, xxiii-xxiv). Solutions include, for instance, planned maintenance activities or the replacement of (worn) parts before they reach the end of their service life. Building on this, maintenance departments can also work proactively. Doing so means anticipating errors before they transpire and deriving measures to prevent any future occurrence. This can, in some cases, significantly increase plant reliability and save costs (Eti et al. 2006, 1238-239). Some companies, mainly medium and large enterprises, are developing independent departments out of maintenance that focus exclusively on increasing plant reliability (Hawkins 2015, 31). In these departments, reliability engineering, as we understand it today, is usually only a fraction of the work of the engineering personnel. In order to mitigate the problems with asset reliability and, therefore, save costs, more and more companies across the globe have invested – at least during the last number of decades – in separate departments with the sole objective of improving the reliability of their assets (machinery) (Madu 2005, 318). It is fair to say that reliability engineering is now a firmly established area in larger firms. Historically, this development started in the aerospace industry, since it is an unmitigated requirement that all failures are prevented at any cost. More and more fields have adopted reliability engineering as the demands of industry have continued to increase (Moubray 1997, 3). Consequently, having a separate reliability engineering department (RED) is a "must-have", indeed, a "prestige department" in larger companies. Setting up separate departments mainly to improve asset reliability is a considerable step, as it is pretty costly. It means providing full-time personnel, who primarily try to solve problems that are not problems today but could appear in the future. It is commonly known and widely accepted that a RED improves machinery's technical condition much more than any general maintenance department can (Calixto 2013, 503-05).

In this context, reliability engineering describes an interdisciplinary field that deals with the life cycle management of a product or system, from design, manufacturing, and installation to maintenance and repair services (Jin 2019, xxiii). Here, various defined processes, methods, and tools are used for dealing with technical risks (Dam 2010, 9). The actual tasks covered by such a RED vary depending on the corporate philosophy.

A model outlining potential activities and tasks for a RED is, for example, described by (Smith 2011, 84-176) in "Reliability, Maintainability and Risk: Practical Methods for Engineers". There are also different models for the meaningful organization of a maintenance department. These are presented, for instance, in "Organisation der Instandhaltung / Organisation of maintenance VDI 2895" (Verein Deutscher Ingenieure 2012, 1-36) or by Ben-Daya et al. in "Introduction to Maintenance Engineering: Modeling, Optimization, and Management (Ben-Daya et al. 2016, 403-06)".

A parallel can be drawn here to general project management or the current issue of the operational implementation of digital transformation. In these areas, too, there are various organizational options for embedding them into the existing operational process (Kretschmer and Khashabi 2020, 86-101). These, in turn, depend on a variety of individual factors. Implementing these topics in a separate focused team in the project field has significant advantages such as simplicity, speed, cohesion, and cross-functional integration (Larson 2007, 25-6), as is the case when implementing digital transformation. In addition, at least one dedicated lead person is needed to drive the change forward efficiently (Horlacher et al. 2016, 1).

The question arises as to what extent independent REDs can positively affect a company, even over an extended period. To put it in a more straightforward way: What are a company's financial expectations when it comes to their reliability engineering department? How can such a department be integrated organizationally into an existing company? How will the success of reliability engineering be measured? Does an independent reliability engineering department positively impact a business? These questions will be answered with the help of a quantitative survey.

Definitions and Limitations

When talking about reliability, many people focus on the product's reliability. However, this is only one part of a vast field. The reliability of the production facilities to manufacture the respective product is, of course, just as decisive for a company's success. Quality and reliability are often equated (Braglia et al. 2007, 420). Nevertheless, this is only partially applicable here. Instead, reliability must be considered as the quality (of a product, a system, a plant, etc.) over a certain period (ibid.).

Blischke and Murthy state that the reliability of a product (system) is the likelihood that the product (system) will perform its designed function over a given time period under standard (or specified) environmental circumstances (Blischke and Murthy 2000, 18).

Reliability engineering can also be viewed from many different angles. Dam describes that reliability engineering is the application of a set of accurately defined engineering processes, methods, and tools used to identify, interpret, and manage technical hazards (Dam 2010, 9).

In this study's context, the term reliability always refers to the reliability of production assets or production equipment. However, the engineering path to reliable equipment is primarily the same as the path to reliable products. Therefore, the same mathematical models and techniques are predominantly used. The reference to software and networks is explicitly excluded.

Maintenance departments with independent reliability engineering departments are usually only found at larger companies or sites (>250 employees, according to Eurostat (European Commission – Eurostat 2021, 1)). In most cases, small and medium-sized enterprises do not possess such independent departments within their organization. Consequently, the majority of the study's focus lies on large companies. No industrial sector is expressly excluded from this study. Still, companies from the chemical and petrochemical industry, in particular, have more often independent reliability engineering departments and are, therefore, strongly represented in this study.

Due to the intense restriction of the possible field of participants, as a high level of expertise is required, it seems – despite a great deal of effort – to be challenging to reach a much larger number of participants to participate. Even though the survey participants are international (for more on this, see sampling), all these participants have a technical background.

There were no questions or even restrictions on the gender of the participants. It must also be considered that face-to-face interviews were impossible due to the Corona pandemic.

Methodology

Unfortunately, the presently publicly available data is insufficient to draw reliable conclusions on the study's questions. In order to investigate the current structures of industrial maintenance organizations – especially concerning reliability engineering departments – an empirical study must be conducted to close this research gap. A substantial number of specialists and executives from international companies at worldwide locations will be questioned. Therefore, a quantitative online survey was chosen to answer the open questions. This results from the fact that this research design is excellently suited to capture a considerable number of cases and numerical values (Bryman 2016, 32).

The results of the empirical study are primarily intended to answer the following questions:

- What are a company's financial expectations when it comes to their reliability engineering department?
- How can such a department be integrated organizationally into an existing company?
- How will the success of reliability engineering be measured?
- Does an independent reliability engineering department positively impact a business?

This study consists of three steps. The first step was creating a comprehensive database using a quantitative online survey which was specifically designed and conducted for this purpose. The survey mainly addressed highly specialized experts and managers in reliability engineering, maintenance, production, and site management. The main aim was to answer the four questions mentioned above but also to collect some supplementary information regarding independent REDs. The second step entailed the analysis and interpretation of the received data. These were evaluated with the support of the SPSS (Statistical Product and Service Solutions) software (IBM SPSS Statistics, Version 25, IBM, Ehningen, Germany). In the third step, the evaluated data was processed and presented.

Survey

An online survey was chosen to collect quantitative data as an empirical research method. This approach was chosen as quantitative-empirical research has become the standard in the social sciences (Best and Wolf 2010, 3). This method allows a clear statistical presentation and evaluation of the results. Raithel also confirms that quantitative or quantifying approaches and methods enable an intersubjectively comprehensible description of complex structures by making social conditions measurable and providing a statistical analysis (Raithel 2008, 8). An online survey has the great advantage of being independent of time and place. Since this research addresses internationally active people, the authors expect a larger and more international group of participants through this survey method.

Survey participants are assured of strict confidentiality and anonymity. Bos state, in this regard, that the reference to the results' absolute confidentiality, which will only be used for the purposes agreed upon, is a matter of course (Bos 2020, 39-48). The survey took place during the spring and summer of 2021. The evaluation directly followed this phase and was concluded by the end of 2021.

Sampling

The questions asked in the survey are highly specific and require a detailed insight into the respective company's specialized area. In order to be able to answer the survey in a detailed and technically correct way, a restriction to a small, very specialized group of participants was mandatory, as exact knowledge of the organization, processes, and costs at the company or site was required. Survey participants included general managers, site managers, production managers, maintenance managers, reliability managers, and reliability engineers. In addition, persons with similar areas of responsibility, such as researchers & practitioners in reliability, a consultant in reliability/lubrication, a professor of mechanical engineering, and a sales technician, were surveyed.

Jungbauer-Gans states that quantitative-empirical social research is oriented towards case numbers as high as possible or sufficient for differentiated statistical procedures. This approach is made in reference to sampling and test theory tenets. On the other hand, studies with small numbers of cases are exposed to the general suspicion of biased selection (Jungbauer-Gans 2009, 6). Biased selection may well arise when the group of respondents is so small that it cannot reflect the full range of possible responses in the field under consideration. For this reason, a sufficient number of participants must participate in the survey to draw a conclusion about the majority. The minimum number of submitted online questionnaires was set to 50. Teddlie and Yu explain that when using probability sampling, it must be large enough to be representative (usually at least 50 units) (Teddlie and Yu 2007, 84).

It is not an easy matter to find a sufficient number of participants for a quantitative survey where the participants group must have such specialized knowledge to answer the questions satisfactorily. For this purpose, various sources were selected. These were personal contacts from the industry, contacts from professional institutions, contacts from universities, and reliability networks and institutions.

Participants are also encouraged to share the survey with experts with similar professional backgrounds. Thus, purposive and probability sampling is combined for the study.

Due to the many different approaches and ways of finding participants, it can be assumed that a strongly mixed group from different professional fields and with different regional origins will participate in the survey, thus avoiding a one-sided response to the questions posed.

For the actual formulation of the questions, the "10 commandments" of question formulation, according to Porst, were followed as accurately as possible (Porst 2000, 2-12).

The questionnaire aims to gain as much insight into the topic as possible; therefore, 26 questions were formulated. For some questions, there was the possibility to give multiple answers. Thus, evaluating some questions may result in a response rate of over 100%. The complete questionnaire is available upon request from the authors.

A pretest was carried out before the survey was released for public access. Executing a pretest is generally considered an indispensable prerequisite for successfully developing a questionnaire (Stockemer 2019, 67-9). For further processing in the IBM SPSS program, the survey data had to be coded accordingly. This coding was performed according to the specifications described by Bryman (Bryman 2016, 293-98).

The possible settings within the online questionnaire directly prevented some errors in the input. For example, entering texts into sections requiring numerical values was impossible. Nevertheless, all data were checked for plausibility, correctness, and completeness without exception. Spelling errors in free-text input have been left as they were. Data cleansing was performed following the procedure described by van den Broeck et al. (van den Broeck et al. 2005, 966-70). Due to the excellent data situation, a basic cleansing was not necessary but was limited to very few individual cases of implausible data.

Results

Participants, Origin, and Qualification

A total of 76 respondents took part in the survey. Unfortunately, the questions were not answered entirely by all participants. For 13 participants, the survey was intentionally closed because they do not have and do not plan to establish a reliability engineering department within their organization. Thus, they would not be able to answer the questions adequately. The questions were scored as far as they were answered for all other questions.

As expected, specialists from all over the world participated in the survey. The geographical focus here was on Europe. Most participants came from the fields of reliability engineering and maintenance. Yet, some other professional groups also participated, as shown in figure 1.

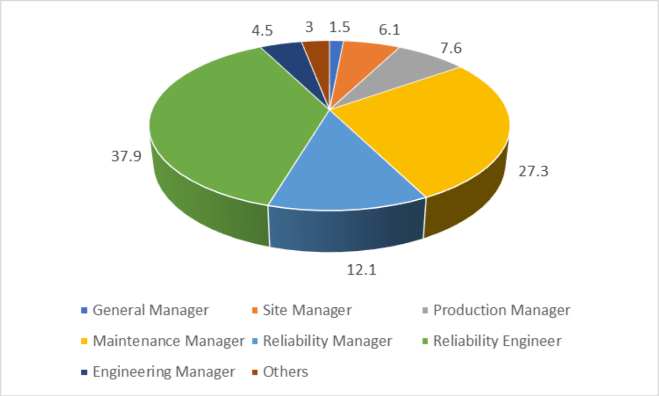

Figure 1. Participating professions [%]

The average number of employees at the participating sites was 727. It can therefore be characterized as a large company (European Commission – Eurostat 2021, 1). The largest site had 5,000 employees, the smallest only 30 employees. The respective maintenance departments (if any) employed an average of 107 people. In the independent REDs, an average of nine people were employed. The largest department occupied 150 associates, the smallest just one person. It is presented that 61.4% of reliability engineering employees have a university education.

Activities, Organization, and Integration of an independent Reliability Engineering Department

Although independent REDs are still a relatively new phenomenon in many industries and geographic regions, 62.1% of participants pointed out that their site already has a RED. Of the participants who have not yet established their own RED, almost half of them (48.0%) would like to establish a RED in the future. The survey ended here for the participants who have neither already established a RED nor want to establish one.

Although participants suggested that there are several ways the RED can be integrated into the existing organization, in most cases, reliability engineering is part of general maintenance (71.7%). Other areas are significantly less represented here (see Fig. 2). One participant stated: "Reliability Engineering needs to support all departments and therefore not be part of any." However, individual responses also show that this department can well be part of cross-departmental teams (twice).

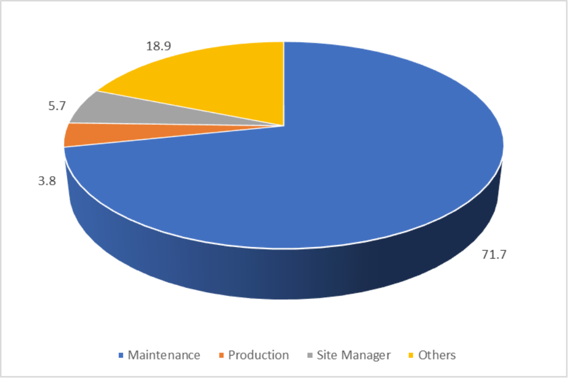

Figure 2. Affiliation of the reliability engineering department [%]

This consequently shows that the majority of the REDs report with 56.6% to the maintenance manager. However, they may also report directly to the site manager (20.8%) or the head of engineering (11.3%). Nobody reports directly to the production manager.

The general maintenance strategy depicts that a purely reactive strategy is no longer common (20.8%). For the most part, preventive (67.9%) and predictive (52.8%) work is carried out. In some cases, several strategies are pursued, depending on the situation. Here it becomes evident that one strategy that fits all assets often does not work. Therefore a strategy mix is used (providing an overall sum >100% as the question result). The study shows that many REDs are allowed to carry out projects themselves, i. e., without the approval of a manager (e.g., asset manager, plant manager etc.) - at least in part. The overwhelming number of participants (83.0%) consider this sensible. 2/3 (66.6%) of those working in the area of reliability engineering do this exclusively—the employees who work only part-time in the department work 66.0% of their time in reliability engineering. Figure 3 shows the main activities of these departments as follows:

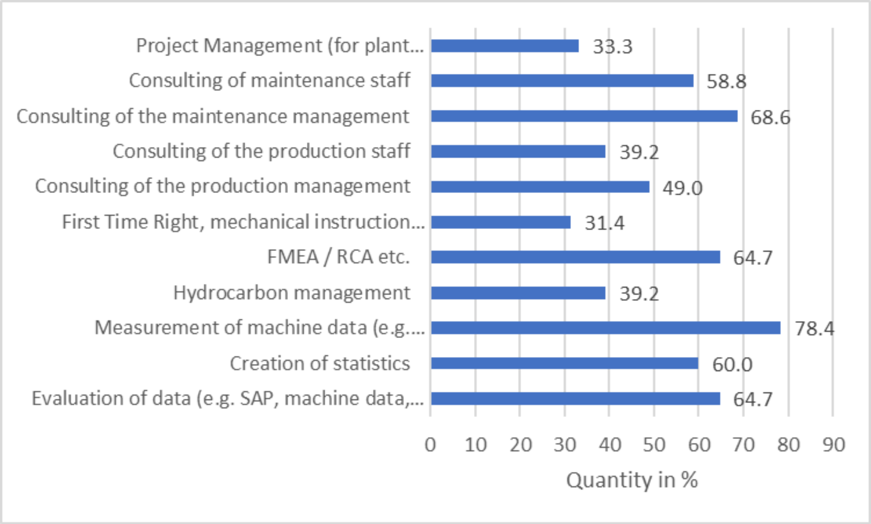

Figure 3. Main reliability engineering department activities (possible multiple answers)

The study showed that only 58.8% of the REDs have their own budget for implementing improvements. The budget varies from 0% to 35.0% of the maintenance budget. It results in an average budget (related to the maintenance budget) of 12.0%.

As in most companies, the participants in the study also use the classic Key Performance Indicators (KPIs) of maintenance costs, production losses, and plant uptime (see Fig. 4). Strict use of these indicators allows the success or failure of the RED's measures to be represented.

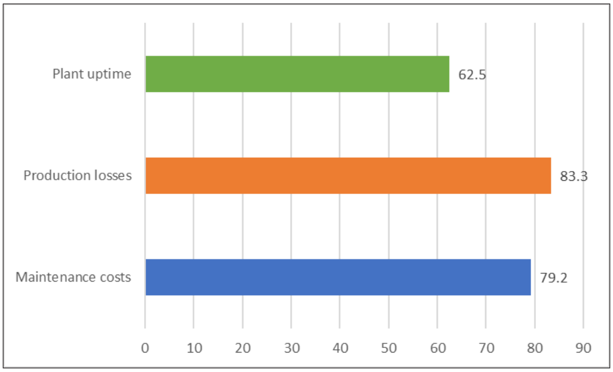

Figure 4. Use of KPIs [%] (possible multiple answers)

Almost all of the participants in the study said that they expect financial improvements from a RED. A large number of participants (86.3%) indicated that reliability engineering has already contributed to cost savings for the site. It should be noted here that some participants state that they have not yet established any reliability engineering department. Adjusted by these participants, savings were generated at 100% of the participating sites. This shows the positive effect that REDs have on the respective company.

Over the past two years (2019 and 2020 were analyzed), the expected average savings compared to the actual average savings achieved for participants that had already implemented a RED were as follows:

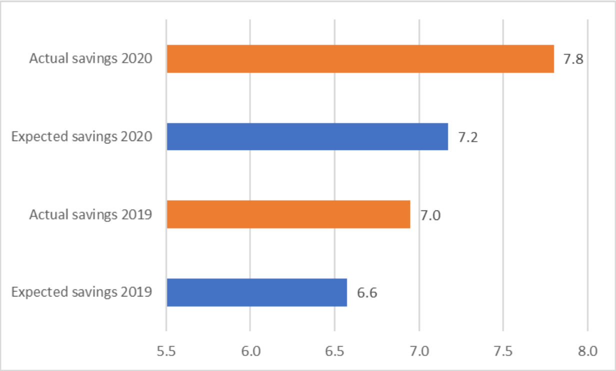

Figure 5. Average reduction of production losses [%]

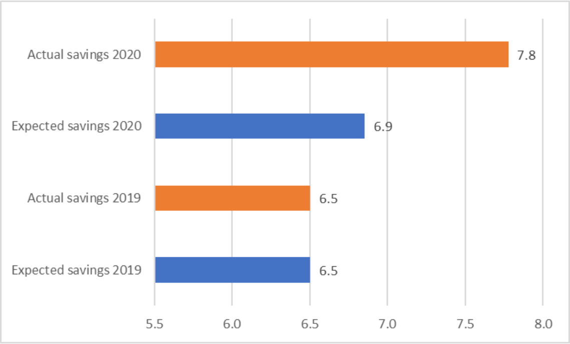

Figure 6. Average reduction in maintenance costs [%]

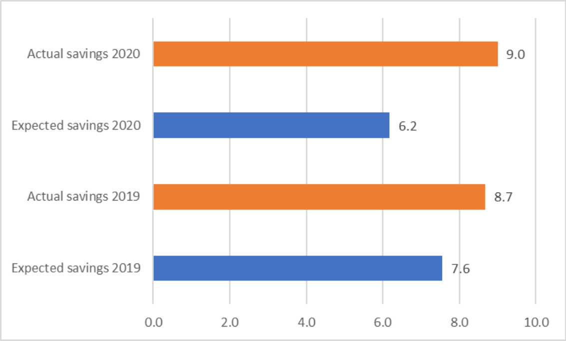

Figure 7. Average extension of plant operation time [%]

Figure 5 shows that the reduction in production losses has exceeded expectations for two years in a row. Regarding maintenance costs (Fig. 6), expectations were precisely met in 2019. These were substantially exceeded in the following year (2020). The average extension of plant operation time (Fig. 7) shows that the savings achieved in this area also surpassed expectations in the same period. In any case, however, there are significant savings in all areas.

Two participants (4.9% of all with an independent RED) who already have their own reliability engineering department revealed that the department did not meet the specified targets.

Looking forward, participants rightfully expect to see continued savings. These expected savings average out to a reduction in production losses by 12.7%, a reduction in maintenance costs by 10.2%, and an extension of plant operating time by 12.2%.

However, the expectations of the individual participants are pretty different. These range from 0% to 50.0% for the reduction in production losses, from 0% to 30.0% for the reduction in maintenance costs, and from 0% to 50.0% for the extension of plant operating time.

Conclusion

This paper's main objective was to investigate the impact of an independent RED on an existing company as well as its implementation in practice. Four main questions were answered in this process to close the research gap.

In order to be able to draw relevant conclusions from a survey, a broadly diversified field of participants was required. Even if most participants originate from Europe and larger companies, there is still a worldwide spread and references to small and medium-sized enterprises. Likewise, despite the required strong specialization, the participants not exclusively came from the reliability engineering and maintenance field. Therefore, the expected approach of a mixed group has been fulfilled, as was intended.

It is now clear that independent reliability engineering departments are by no means isolated phenomena today. They are already firmly established in many companies or will be launched soon.

(i) What are a company's financial expectations when it comes to their reliability engineering department?

In most companies, substantial financial savings are expected from REDs – consistent not only once but recurring yearly. The results show that the various participating companies have clear financial expectations for introducing REDs. In the years under consideration (2019 and 2020), the companies that have already implemented a RED expected an average reduction in a production loss of 6.9%, a reduction in maintenance costs of 6.7%, and an increase in plant operating time by 6.9%.

(ii) How can such a department be integrated organizationally into an existing company?

REDs are classically integrated into the general maintenance organization in most companies. However, it is also apparent that other organizational forms are possible but often not utilized. Particularly departmental or cross-site organizational forms are used. Consequently, most reliability managers report directly to the overall maintenance manager but also to the site manager.

(iii) How will the success of reliability engineering be measured?

To measure the success of the reliability engineering department, the "classic" KPIs are predominantly used: maintenance costs, production losses, and plant uptime.

(iv) Does an independent reliability engineering department positively impact a business?

It has clearly and broadly been demonstrated that all REDs have achieved savings in recent years, some significant. Correctly, it is expected that savings will be achieved noticeably and recurrently. As a result, these departments had a thoroughly positive effect on the company's competitiveness.

Furthermore, the study also showed that the maintenance strategy is not precisely defined in many participating companies or is deliberately a mixture of several strategy forms. In any case, there is a clear shift away from a purely reactive maintenance strategy.

In addition to that, it is demonstrated that the majority of the employees in the reliability area work full-time in that field. The field of activity of the employees in this area is very diverse. The focus is undoubtedly on "classic" activities such as recording, evaluating, and assessing machine data and creating Failure Mode and Effects Analysis (FMEA) and Root Cause Analysis (RCA). On the other hand, advising employees and managers is an integral part of their work.

Implications

The study results show that an independent reliability engineering department in modern maintenance positively affects the companies studied. Such a department may well achieve significant savings. Even if the current standards for maintenance organizations do not mention such a department or only marginally, the study shows that many of the companies investigated have already gone the way to an independent RED or are planning to do so in the near future. It is, therefore, advisable to rethink today's maintenance organizations. An independent RED can contribute to the profit of a company.

Critical Appraisal

Due to the given characteristics of a quantitative survey, it is only possible to understand specific backgrounds and intentions to a limited extent. In order to be able to classify the survey results better, some of the questioned variables of the quantitative survey must be deepened and validated. It is recommended that various variables be examined in depth in expert interviews and combined with the results obtained. It could also be interesting to investigate the size of a company at which an independent reliability engineering department can operate profitably.

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