Practical Database Design for Industrial Maintenance System

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Abstract— **This paper describes how a database design can play an important role for developing practical industrial maintenance system. The good database design will in return give a better information sharing and good system in term of data accessibility. The design of the database are presented and illustrated by a case. The preliminary result presented to show that is possible to access a more correct view of the situation in the system development and thereby obtain a better base for making maintenance decisions. The database supports the development of applications e.g. for monitoring the performance of a maintenance in the production, for deciding the most appropriate maintenance policy or for simulating possible maintenance solutions.**

Keywords-database design, maintenance, decision support

I. INTRODUCTION

The importance of maintenance has been stressed by an increased use of automation and management systems and philosophies like Just in Time (JIT) and lean manufacturing, where the consequences of problems and disturbances in the production process are diverse and severe [1]. Furthermore, maintenance has been described as an integrated and coordinated part of the production process [2] while Waeyenbergh and Pintelon [3] describe it as being about partnership. In order to have a good maintenance management system, a practical and proper database design is essential. An information system development process needs a data to be stored in database. This is critical when most of the data came from different units or sections. To ensure the information gathering will not breakdown, a systematic and practical database design is important.

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II. LITERATURE REVIEW

Manufacturing industries have realised the importance of performance monitoring and follow-up by technical measurements and indicators, and in the literature this has been addressed by many authors in different contexts, see [4];[5]. To be able to show the impact of maintenance on production and on overall business, data from various Information Technology (IT) systems serving different working areas relevant to maintenance are needed, as well as possibilities to process, interpret and analyse the data. This means that data from administrative IT systems, industrial IT and non-automatic sources must be collected in order to form a relevant set of technical and organizational maintenance data. In major plants, especially in production intensive industries, you are likely to find most data in the corporate IT systems, but they are often distributed over several databases and IT systems and even geographically separated.

In order to avoid data heterogeneity and information standardization problems, the integration could be carried out on the data level instead of on the IT-system level, by defining one's own set of data needed for e.g. maintenance management. However, to enable this, criteria and procedures for the data selection as well as for the data collection are necessary in order to ensure the quality of input data and of the decision-making process itself. Data alone cannot lead to cost-effective decisions, though. Pintelon and Van Puyvelde [4] point out the importance of a well-functioning computerised maintenance reporting system and also the fact that most systems in this area are limited only to budget reporting. Based on the discussion above, a system that utilises the data for monitoring and assessing the performance of maintenance is needed. The system must also allow for tracing the reasons behind a deviation in maintenance performance.

III. MAINTENANCE MANAGEMENT AND ITS INFORMATION NEED

In the following, the authors describe the data and information requirements for the monitoring and improvement of maintenance performance. The data need for different maintenance strategies are subsequently addressed. The chapter concludes with a review of current information modelling standards and practices used for maintenance and its management. This chapter is important since the need to have necessary information to design a good database. By gathering related information, the system to be developed can be practically applied to the given scenarios.

A. Data and Information Need for Improvement of Maintenance Performance

Since maintenance is not an isolated and independent function in a company, actions taken in maintenance will affect other company processes [6]. Fig. 1 illustrates the information sharing need of maintenance, where the main information flow between maintenance and closely related processes such as quality, production logistics, life cycle cost (LCC) and overall management is described [7].

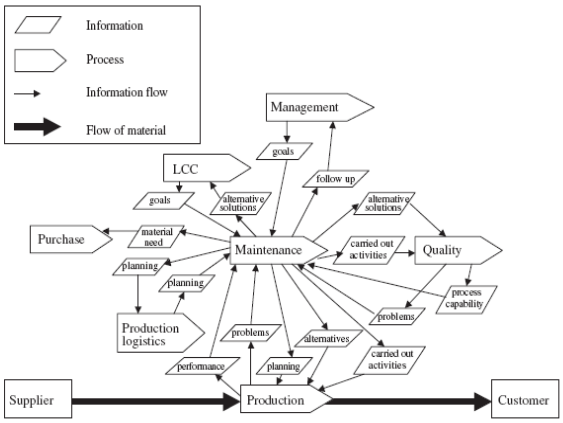

Figure 1. Information flow between maintenance and other corporate process

Operational and tactic maintenance decisions concern the maximum use of available maintenance resources in the form of employees, skills, tools and priority decisions of when to do what [8]. These decisions require advanced tools for planning and simulation, as well as detailed on time information about the current production assets and maintenance resources and their status, i.e. the information is gathered from the corporate systems when needed.

There is also a need to evaluate the performance at all levels of maintenance control. If no follow-up is made, improvement is impossible. Therefore, decision support in the form of performance measures and traceability to root causes is needed [9]. The potential of improving the maintenance activities has grown tremendously with the new technologies and methods that move the focus from reactive to predictive maintenance [10]. Matching innovations within maintenance with the development in the IT area makes it possible to collect and process vast amounts of data rapidly and at a relatively low cost.

B. Data and IT Need of Maintenance Strategies

A maintenance strategy is defined in EN 13306:2001 as a management method used in order to achieve maintenance objectives [11], while a policy describes the interrelationship between who is to carry out maintenance, where to carry out maintenance and the set of maintenance actions to be carried out [12]. Table 1 illustrates what kind of maintenance management IT support could be of interest, depending on the maintenance strategies applied within a company. If a company currently uses mainly preventive strategies, but is in the process of gradually moving to more predictive strategies, a regular computerised maintenance management system (CMMS) with information-sharing capabilities, including the capability to retrieve data from condition-monitoring devices, would be appropriate. A company might also consider using an enterprise resource planning (ERP) system for maintenance management, especially if its overall IT strategy is to use integrated IT solutions.

TABLE I. SUITABLE MAINTENANCE MANAGEMENT SUPPORT DEPENDENT ON MAIN MAINTENANCE STRATEGY USED

Maintenance strategy	IT System
Reactive	Stand-alone CMMS with basic functionality
Preventive	Stand-alone CMMS with information-sharing possibilities with other IT systems
Predictive	CMMS with information-sharing possibilities with other IT systems and condition-monitoring technology *alternatively* ERP system with information-sharing possibilities with condition-monitoring technology
Proactive	CMMS with information-sharing possibilities with other IT systems and condition-monitoring technology plus extra decision support *alternatively* ERP system with information-sharing possibilities with condition-monitoring technology plus extra decision support

C. A Review of Current Standards and Practices for Maintenance Information Modelling

The modelling of information for maintenance has become important, especially with the introduction of predictive and proactive maintenance strategies. Data requirements are vast and demand a structured approach for defining, identifying and retrieving relevant information. Several models and methods have been developed to support enterprise integration, especially focusing on the definition and sharing of corporate data and enabling smooth IT integration, such as the Computer Integrated Manufacturing Open System Architecture (CIMOSA), the General Reference Architecture Model (GERAM), the Open System Architecture for Enterprise Application Integration (OSA-EAI)developed by Machinery

Information Management Open System Alliance (MIMOSA) and the International Standard IEC 62264.

IV. IMDST-A DECISION SUPPORT TOOL FOR MONITORING AND ASSESSING MAINTENANCE TECHNICAL

In the following, the work on developing and designing a DSS, with its database, for monitoring and assessing maintenance technical is described. The DSS is called IMDST, an intelligent maintenance decision support tool. IMDST is a system that is chosen as a practical illustrative case. This is because the tool describes how the database design is important and can be utilised in a real-world application.

A. Decision Support System Development

In 2007, the project under Universiti Teknikal Malaysia Melaka (UTeM) is developed and tested [13]. This model is further analysed in order to highlight the possibilities of transferring the concept into a computerised DSS. For this purpose a preliminary study is conducted on a palm oil mill (POM) in Malaysia [14]. The conceptualisation of the DSS in the form of IMDST is shown in Fig. 2. One aim of the IMDST project is to develop a DSS that could be integrated with other IT systems at different levels: the integration of IMDST within the existing IT systems or the coordination of IT systems so that IMDST can make use of the data resources available - in other words, integration on the database level.

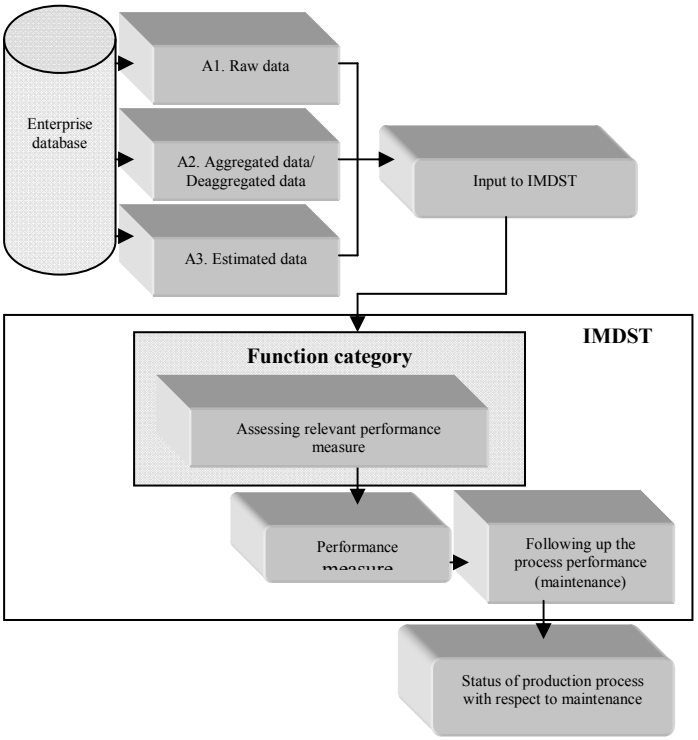

Figure 2. Conceptual model of a maintenance DSS

To assess the factors and measures presented above, IMDST uses three kinds of data:

1) Raw data: Data which can be gathered directly from the databases at the company.

2) Aggregated and disaggregated data: These types of data processing may be necessary if the required input data come from several sources or if they are on too high an aggregation level.

3) Estimated data: These data are usually not available in the databases of the company and must be estimated on the basis of other technical and financial factors, using the company's experience, database, and mathematical or statistical relations.

B. Database Design

Fig. 4 is partly a graphical database design of IMDST, where data and information needs within maintenance are represented as entities with their attributes and relationships. The entities are denoted as rectangles, attributes as ellipses and relationships between the entities as diamonds in the design, see description in Fig. 3. The cardinality, i.e. the number of instances of one entity that can be associated with each instance of another entity, can be one-to-one (1:1), one-to-many (1:M) or many-to many (M:N). The database design of IMDST does not describe a traditional planning/execution-centred view on maintenance as in a computerised maintenance management system. The development team has instead chosen to view maintenance as an integrated part of the production process.

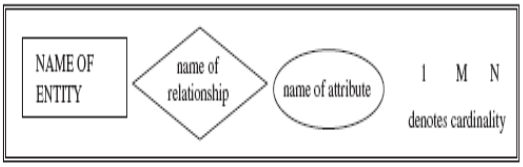

Figure 3. Graphical ER notation

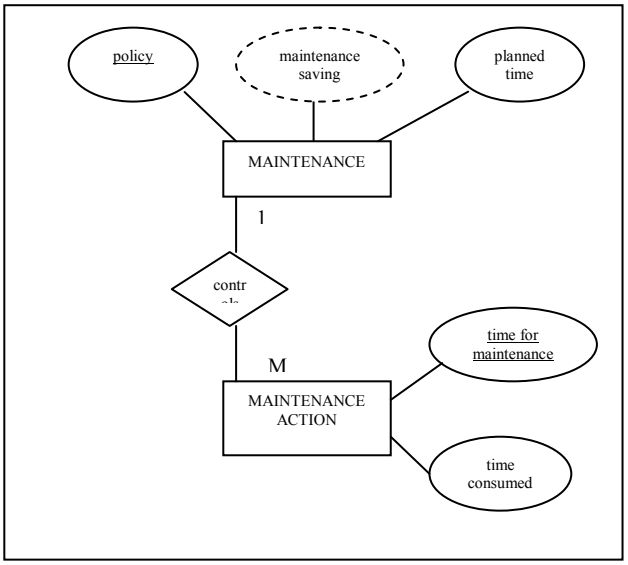

Figure 4. Database design of maintenance planning related data

V. PRELIMINARY RESULTS

A series of implementing and testing the IMDST to the users at the case studies site have been conducted. The preliminary result shows that it is satisfactory but needs a further improvement. The users also agreed that IMDST particularly in the information gathering and retrieving enables the improvement of maintenance performance. They also agreed the system presents to the user a view of the situation based on data from maintenance. This makes it possible to consider effects of maintenance that are often neglected or difficult to take into account, for instance maintenance cost losses due to performance inefficiency.

VI. CONCLUSIONS

As described, a database design can be an important instrument for decision-making in maintenance. Since it includes data from several relevant working areas, it can form a basis for a quick overview of the current situation. Applying the database concept makes it possible to access a more correct view of the situation in the production by data integration and thus obtain a better base for making decisions in maintenance. Furthermore, since it gives easy access to relevant on time data, it enables the detection of deviations at an early stage, thereby avoiding unnecessary costs.

In realising the idea of a database design, methods and standards such as GERAM, CIMOSA, OSA-EAI and IEC 62264, can be useful for describing the integration of maintenance and other functions in the enterprise and for sharing corporate data. Each method and standard has a slightly different focus compared with the others; therefore the integration of methods is important, such as the work driven by MIMOSA. If the database is combined with computerised decision support, it can become a powerful tool for improving internal effectiveness. It is possible to develop applications for several purposes that can benefit from a database design, such as

- applications for technical performance of a production process;
- applications for deciding what maintenance policy is the most effective in a certain situation;
- applications for the simulation of possible maintenance solutions and their impacts on other related working areas.

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