Maintenance Scheduling based on the Analysis of Building Performance Data

H.U. Gökçe, P. Stack, K.U. Gökçe, K. Menzel
IRUSE, University College Cork, Ireland

ABSTRACT: Many efforts are invested in the facility management (FM) of buildings. This can be a major contributor to the reduction of the overall energy consumption and the reduction of CO_2 emissions. Sophisticated Building Services Systems are available, integrating conventional energy systems with renewable energy systems. However, the performance of installed systems is insufficiently monitored and analysed leading to a slow degradation of the system performance and finally to increased energy consumption and CO_2 emissions. This paper introduces an Information Technology (IT) based solution to assist the maintenance process.

1 INTRODUCTION

In order to sustain efficient operations of a facility or a building, maintaining the operation of a facility's plant and machinery is a necessity. Inefficient building systems consume excess energy which leads to greater running costs for facility managers. A more effective maintenance plan should incorporate many aspects essential to the efficient and optimal operation of building systems. With the benefits of new sensing and metering technology a new dimension for improved monitoring of buildings and equipment provides a more complete platform for facility management applications.

Maintenance should be an integral part of any energy management system. Maintenance keeps equipment from failing, helps keep energy costs within reason, helps prevent excess capital expenditures, contributes to the quality of a product and is frequently necessary for safety (Capehart, Turner & Kennedy 2006). For any facility, there is a responsibility to ensure the correct functioning of building elements. Replacement of certain elements can be a costly exercise as some may be ingrained within the building structure and so building services engineers must ensure correct and standardised operations with equipment.

For maintenance to occur there must be correct provision of resources in order to complete a maintenance task. Most building maintenance teams have a number of spare parts available in the possibility of a critical function breaking down. One must also take into account the manpower and skills needed in order to complete maintenance activities. Some companies or building owners hire consultants and contractors to provide facility management services to specific or all systems that need to be maintained within their building structure.

Advances in sensing technology over recent years provide a suitable framework for the collection and analysis of building performance data and processes. A *"On World"* report on the use of wireless sensors claims that "only 5 percent of the most mission critical equipment is monitored today. The rest is monitored manually or not at all (Sirico, Parker & Thorn). Recent research shows that the adoption of a wireless sensor platform can assist with energy efficiency in building performance and the produced flow of monitored data forms the basis for a Computer-Aided Facility Management system (Menzel et al. 2008).

Currently 85 percent of the European buildings are older than 20 years; 60 percent are older than 40 years and 30 percent are pre-war buildings (Itard 2008). In result, many companies in the construction area are currently undergoing a shift from new builds towards the facility management, renovation and retrofitting of existing buildings. Consequently, new FM and maintenance strategies are being established focusing on the optimisation of building energy consumption.

In this paper we introduce maintenance scheduling based on the building performance data which lead to optimized building operations.

Maintenance scheduling is a system which integrates and coordinates building facilities with respective maintenance services and resources. With the use of standard task workorders a whole management system can provide a deeper insight into the operations of the building both from financial and energy perspectives. Based on this insight, more tailored or effective decision making can be achieved with respect to facility management.

2 FUNDAMENTAL CONCEPTS

This section is an overview of the fundamental concepts involved in order to create an effective maintenance platform. As maintenance is traditionally classified under the division of FM within organisations our solution needs to incorporate existing scenarios. Also, standard models in maintenance industry must be considered as there is a need for any new model to be compatible with existing practices. Furthermore, business process modelling, building performance modelling and collaborative scenarios can be tailored towards a company's standards and preferences. Finally a review of how building information is maintained and existing database products on the market.

2.1 *Facility Management Models*

The maintenance activities of a facility can be viewed from a number of distinct perspectives. In "Facility Management Towards Best Practice" (Barrett & Baldry 2007) five widely used models in Anglo-American society are described as follows:

- Office Manager Model is an approach where FM is a role under taken by an office manager. The office manager is responsible for decision making, budgeting and expenditure. FM tasks are usually carried out by consultants or contractors where necessary.
- Single Site Model constitutes an organisation which has a FM department but operate only on a single site. FM activities can be assigned in-house and/or contracted services. The FM group decides how to distribute the allotted budget.
- Localised Sites Model consists of organisations that have buildings in multiple sites. FM jobs are assigned in-house and/or contractors. The headquarters (HQ) control expenditure, policy and technical assistance while operational decisions can be made locally, on site.
- Multiple Sites Model applies to large organisations that operate over a large geographical area. Operational tasks are under taken at regional level. The HQ role is to ensure resource allocation, standard setting, policy, planning and project management.
- International Model externs the Multiple Sites model for organizations that operate across international boundaries. The FM team at HQ provides policy, standards and resource allocation. Regional offices are responsible for operational tasks and allocation of budget.

Based on these factors the design of an organisation's maintenance scheduling tool should incorporate the ability to monitor and maintain multiple buildings over a large geographical area, converse with HQ if necessary for decision making relative to expenditure and policy and finally, support communication with contractors and consultants. Therefore, the implemented model should deal and serve to all models that are envisaged.

2.2 *Maintenance Planning Models*

For a FM strategy to be implemented within an organisation, a structure for maintenance activities must be defined. Core to every maintenance model is a scheduling system to handle tasks as they occur either on scheduled or reactive basis. Available resources must be taken into account when dealing with task allocation as manpower, skill set, stock, retrofit and expenditure are basic requirements in order to complete the activity.

Depending on the industry of the organisation, FM tasks necessary to support manufacturing, production or airlines may need to be integrated with the overall process planning. A higher degree of maintenance is relative to a better quality of production but likewise, the greater the maintenance time then the less production can be performed. Maintenance costs normally accrue from man hours, materials and indirect costs (Budai, Dekker & Nicolai 2006).

Reasons for sufficient planning in maintenance activities have been highlighted by Gits (Gits 1994) include the retention of large maintenance staff for emergencies, utility and services expenses for steam, electricity, gas, water, etc., decrease the cost of repair but maintain the quality and operating capacity of machinery and failure to deliver on time may lead to loss of business.

An approach to optimise the maintenance schedule in a production system should involve safety, health and environment objectives, maintenance costs and costs for lost production (Vatn et al 1996). There can be many influences from critical factors when creating a maintenance system and each factor may need to be assigned a priority if scheduling conflicts arise.

Many maintenance policies exist (Wang 2001) so in general there are three general approaches to maintenance planning (Budai, Dekker & Nicolai 2006):

- Corrective Maintenance is classification of maintenance that occurs in response to a break-down, request or other malfunction that inhibits the building operation. Maintenance tasks are carried out in direct response to a failure and are defined to solve the failure event in a prescribed manner.

- Time-based Preventative Maintenance is a series of scheduled inspection routines on building plant. In this case failures can be seen before a failure may occur. Building elements need to be classified to ensure an optimal inspection routine interval is chosen as there is a trade off between inspection costs and failure cost.
- Condition-based Maintenance is similar to time-based preventative maintenance but provides a more optimal solution as the interval is relative to the decreasing performance of the building systems. Implementations tend to focus on information details of equipment such as lifetime, running hours and levels of production rates. Mathematical models can be used in order to calculate the optimal inspection strategy (Chelbi & Ait-Kadi 1995).

Combining a well defined maintenance plan with a coordinated layout of a wireless sensor network (WSN) relative to key monitoring aspects of a building's equipment provides to basis for a remote monitoring scheme. With this flow of information from building elements the solution must alert the Facility Manager when failures occur or reach a threshold at which an inspection should be performed. A new complexity is added to the FM activities as the WSN must be maintained and changes in building equipment must be accounted for.

2.3 *Business Process Models*

The start point for process management solutions can be found in the early 70's with the office automation prototypes (Zisman 1978) which generally focused on the automation of human-centric processes. Recent developments in the area of web services choreography have discounted the organisational aspect of workflow solution and focus exclusively on the coordination of control flow structures (zur Muehlen 2004). Furthermore, the proposed standards such as: WSCI (a subset of BPML), (Arkin et al 2002), WSCL (Banerji et al 2002) and BPEL4WS (Curbera et al 2002) do not contain any notion of human activity performers. Instead they are focused on the technical coordination of inter-enterprise processes with limited or no human intervention. While some initiatives focus on the automation of mainly technical processes, such as the automated data exchange between different applications, some vendors stress the organisational aspect of their solutions (Orlawska et al 2003).

From this standpoint, to enhance, harmonise and eventually standardise FM process patterns for initialising and operating maintenance processes, and to support technical coordination with human intervention which is also not provided yet, a need is observed for an integrated business process approach.

Currently, a number of BPM tools available for users to model their existing business processes. These models can be tested with actual data representing current scenarios and simulate existing practices. Based on the output of these simulations the process model can be refined to give an indication of the optimal process pattern.

Some business process modelling techniques are Business Process Modelling Notation (BPMN), Event-driven process chain (EPC), IDEF0 and Unified Modelling Language (UML).

For a maintenance scheduling system to relate to business processes a number of BPM software applications are also available. Architecture of Integrated Information Systems (ARIS) which supports EPC and Business Process Execution Language (BPEL) form a programming language which can be accessed by enterprise applications. The association of business processes to maintenance activities produces a flexible maintenance plan that is prioritised relative to changing business goals.

2.4 *Collaborative Scenarios*

In response to changing markets and competitive impacts on business goals there is a change of organisational structures in order to form collaborative networks (CN) (Camarinha-Matos 2005), virtual corporations (BusinessWeek 1993), virtual networks (Cravens & Piercy 1994) and virtual enterprises (Cardoso & Oliveira 2004). CN can be a viable option for service-oriented exchange between companies as expansion in either company is a high market risk.

Organisations who own or who's employees inhabit building premises have the option to employee FM staff or the outsource FM activities. The facilities require specialised domain knowledge of structural, mechanical and electrical engineering standards. The FM activities may be negotiated with FM service providers on a contractual basis.

In order to identify potential collaboration there is a need to identify the stakeholders relevant to the maintenance processes (Allan, Menzel & Iqbal 2009). A building owner holds service contracts to multiple FM providers but also provides office space to tenant clients. The FM team need to liaise with tenants to fulfil thermal comfort and fault requests.

Any maintenance system must also consist of daily schedules of tenant activity as access to the fault area may be required. Maintenance may not be possible within certain operating hours also as certain faults may not be critical to core business functions.

The importance in defining a schedule that infiltrates task priorities and stakeholder availability is essential for efficient maintenance. Plus a detailed reporting procedure to assist classifying the fault and avoids vagueness.

2.5 *Building Performance Models*

Various frameworks have been formalised in order to model the lifecycle of buildings. Standard stages in building lifecycle include design, construction, commissioning, and operation and maintenance to create a full building assessment. "There is no continuity to the process of building performance assessment through the building lifecycle" (O'Sullivan et al 2004).

Building performance models examples such as the International Council for Building (CIB) Performance Based Building Program (PeBBu 2001), US Green Building Council's LEED Green Building Rating System (LEED 2003), the International Code Council (ICC) Performance Code for Buildings and Facilities (ICC 2000) and the US Department of Energy (DOE) High Performance Metrics Project (US DOE 2002) provide platforms to describe facilities. The current trend is for buildings to be assessed at initial design stage based on a Computer-Aided Design (CAD) model and uploading relevant environmental and required performance information to simulation tools.

Another aspect to building performance and operation of energy consuming systems is the use of energy-related performance metrics (O'Sullivan et al 2004). Examples include the US DOE High Performance Metrics Project (US DOE 2002), the ANSI/ASHRAE Standard 105-1984 (RA99 1999) entitled "Standard Methods of Measuring and Expressing Building Energy Performance" and CIBSE Guide F (CIBSE 2004) which highlights Energy Use Intensity (EUI) values, measured in kWh/m2/per year, for different building types such as office and sports center.

To formulate a measure of building performance that can be interpreted by a maintenance scheduler will require interpretation and aggregation of monitored data. Current BMSs operate on the basis of a live stream of sensor data and a set of pre-calculated intervals for operating building systems. The scenario modelling technique for holistic environmental and energy management provides a flexible framework to incorporate overall building operation in the context of the building energy manager (O'Donnell 2009). This performance framework provides a suitable platform to translate building performance data in respect to operation levels through the application of standard engineering formulae.

2.6 *Building Information Models for Data Acquisition*

The concept of a Building Information Model (BIM) describes an integrated data model that stores all of the information relevant to a building throughout the building life cycle. The BIM is a central data model where all information can be accessed by a variety of tools dealing with the entire building definition (O'Sullivan & Keane 2005).

In order to examine the potential for making different Architectural, Engineering & Construction (AEC) software applications work together, 12 companies in USA established an organisation namely International Alliance for Interoperability (IAI) in 1994. The main aim of this initiative was to identify the specifications and enabling interoperability between AEC/FM applications from different software vendors and publish them namely Industry Foundation Classes (IFC). Related with fragmented and distributed nature of the construction environment and set of object models, IAI defined the model requirements such as disciplines within the AEC/FM processes, life-cycle stages of the projects, level of details and software applications.

2.7 *Current Database Solutions*

A database is a collection of related data. By data we mean known facts that can be recorded and that have implicit meaning (Fundamentals of Database Systems 2004). A data warehouse is also a collection of information as well as a supporting system. Data warehouses have the distinguishing characteristics that they are mainly intended for decision-support applications.

There are software vendors that provide database and data warehouse solutions such as MySQL, Sybase and Oracle.

In order to integrate different data sources under one repository for decision support a data warehouse system can be developed by utilising the Oracle version 11g. A data warehouse system is capable of integrating the data extracted from BIM, collecting data streams from sensor network, perform data aggregation to monitor building performance and support decision making.

3 OVERALL PROPOSED STRUCTURE

On the basis of given fundamental concepts and global requirements, a maintenance scheduling model which is based on the analysis of building performance data is detailed in this section.

The findings of ITOBO (2008) research cluster who's researchers are currently under taking a study of monitoring building performance through the use of BIMs and the collection of data from a WSN (Menzel et al 2008, Spinar et al 2009) are used as a baseline for the FM solution.

ITOBO focuses on applying FM standards on building performance levels and delve into aspects of building control. Utilising data warehousing methodologies on the flow of data from both the existing BMS and an additional WSN deployment, a basis is provided to extract relevant aggregated building performance data for a maintenance scheduling system.

In order to deploy the system, the Environmental Research Institute (ERI) Building which is owned by UCC (Kennett 2005, Croly 2007) is used as our living laboratory. The ERI building will be used to test and validate our results

ERI is managed by a general manager and caters for multiple organisations with laboratory, office and meeting spaces available. A Cylon BMS was installed by McCool Controls using a wired backbone to connect to its sensors, meters and actuation nodes. FM requests are sent to UCC Buildings and Estates (B&E) branch, which also remotely monitor the facility. Maintenance activities including inspection, calibration and replacement of faulty equipment are contracted to Sirus Engineering. Given this information the ERI building would be classified under the Localised Sites FM Model. The FM software used by B&E is a helpdesk application and they do not have a system for recording maintenance work orders for quality reviews and audits.

3.1 *A Road Map for Maintenance Scheduling Platform*

In order to provide a maintenance scheduling platform 5 generic steps should be followed.

- The first step is to create a list of equipment that need to be maintained. This list will form the basis from which we can define a maintenance plan.
- The next step requires a set of data structures to store and retrieve information.
- Once data is collected, an interface must be created in the third step to allow the maintenance scheduling to extract relevant views of the building performance and other FM resources critical for planning.
- With the aid of process patterns, the scheduler can produce an insight into how different activities are interrelated and produce a more effective maintenance solution.
- The final section presents an example of how an initial development supports a more complete maintenance management system.

3.2 *ITOBO Maintenance Platform*

From these maintenance scheduling platform steps, an initial software platform design, Figure 1, has been created by the ITOBO research cluster to incorporate aspects of building performance to support a facility management application. The result of the decomposition is specified in the form of a Unified Modeling Language (UML) package diagram.

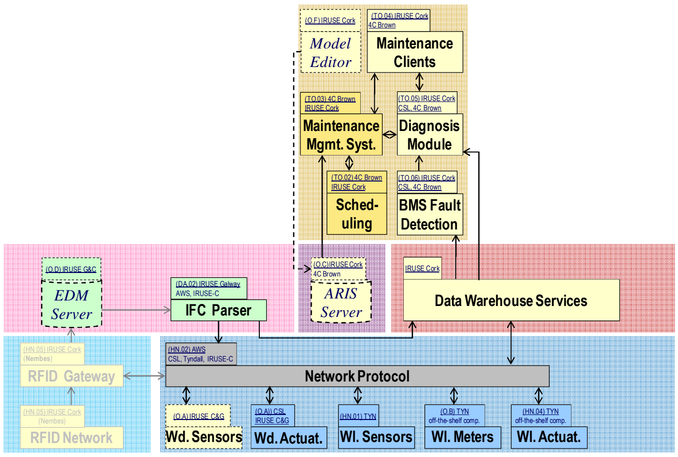

Figure 1: ITOBO Platform Scenario 3 Package Diagram: Scheduling and Management of Maintenance Activities

Building performance data is be monitored by a combination of wired and wireless sensors, meters and actuators. With the aid of Express Data Manager (EDM) server, the building information can be extracted from a CAD model of the ERI. Additional occupancy details are available from an RFID system.

The Data Warehouse Services collects building information, in this case specifically for the purposes of maintenance, and provides data interpretation with the production of materialised views focusing on building operation performance.

An ARIS server can be accessed to supply process information relating to maintenance activities.

In order to automate the FM tasks, Fault Detection and Diagnosis modules need to detect if or when a failure is about to occur and to find the solution to solve the event.

The Scheduling component can then calculate a schedule according to the preferences, standards, resources and set of maintenance tasks collected by the Maintenance Management System.

Finally, Building Engineers will be presented with a set of tasks and information describing the work needed.

Figure 2 presents a description of the basic process which must be integrated in a maintenance scheduling application.

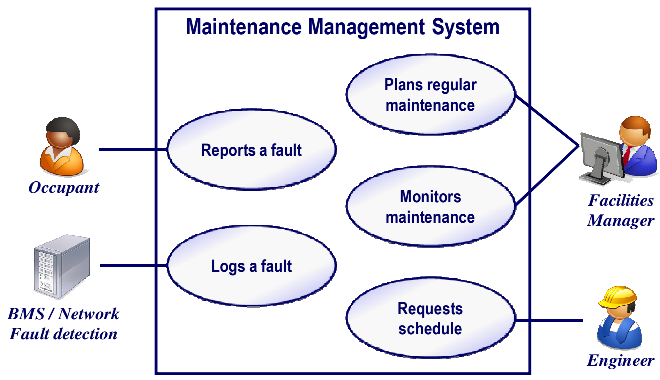

Figure 2: ITOBO Platform Scenario 3 Use Case Diagram: Scheduling and Management of Maintenance Activities

These processes highlight the need to link building performance monitoring to the planning of maintenance activities. Preventative and corrective maintenance tasks, based on fault reporting, are the building blocks for a maintenance scheduler to compute. The scheduler produces an optimum schedule respective to available resources, priority of the tasks and essentially to minimise energy consumption.

3.2.1 *Use of Building Performance Data in Maintenance Scheduling*

To address the need to carry out automated building performance analysis and diagnostics there is a need for a systematically-developed building performance framework. Scenarios should also clearly describe the support necessary to relate equipment performances with respect to scheduling and maintenance. The maintenance scenarios entail developing a monitoring tool that can signal anomalous system behaviours (i.e., the presence of a fault), and a model based diagnosis platform that isolates the root fault entailed by any anomaly signalled by the user or automatically detected by the overall system.

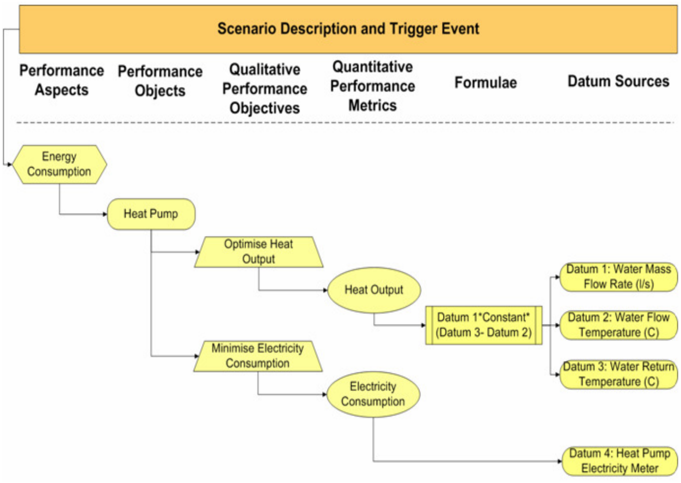

Figure 3: Performance aspects of Geothermal Heat Pump from BuildWise project

Applying the building performance framework adds context to the data stream received from sensors and meters monitoring equipment. In Figure 3 there are two performance measures that can be used to evaluate the Geothermal Heat Pump. The primary role of the heat pump is to generate heat energy and support the hot water and heating systems. If the level of heat output drops below a particular threshold, depending on environmental conditions, a failure can be detected and a maintenance task can be created without the need for consultants.

At the same time electricity consumption can be metered to see coefficient levels of performance against heat output which provide a key indicator as to the energy efficiency of improved maintenance.

3.2.2 *Use of Data Warehouse in Maintenance Scheduling*

This step addresses the storage, aggregation and representation of data collected from different sources in order to support decision making process of different stakeholders (e.g. owner, operator, user/tenant). Compiled performance data includes:

- Energy consumption data (conventional and renewable sources)
- User comfort data (temperature, CO_2-level, humidity, lux-level)
- Environmental impact data (CO_2-footprint)

Information management section consists of:

- A data warehouse architecture with extraction, transformation and loading (ETL) algorithms for building performance analysis.
- Graphical User Interface (GUI) for each user role (owner, operator, occupant) which addresses their specific needs.

A data warehouse is a subject oriented, integrated, time varying, non-volatile collection of data that is used primarily in organisational decision making (Inmon 1992). According to Widom "The topic of data warehousing encompasses architectures, algorithms, and tools for bringing together selected data from multiple databases or other information sources into a single repository called a data warehouse, suitable for direct querying and analysis" (Widom 1995).

In our case data warehouse system is used to provide solutions for building performance monitoring, since it transforms operational data into strategic decision-making information. The aim of the Data Warehouse is to:

1. Collect dynamic data from different sources such as wired/wireless sensors and meters.
2. Map the dynamic data with data extracted from CAD tools, energy simulation tools and performance specification tools.
3. Perform n-dimensional data aggregation to support decision making process.

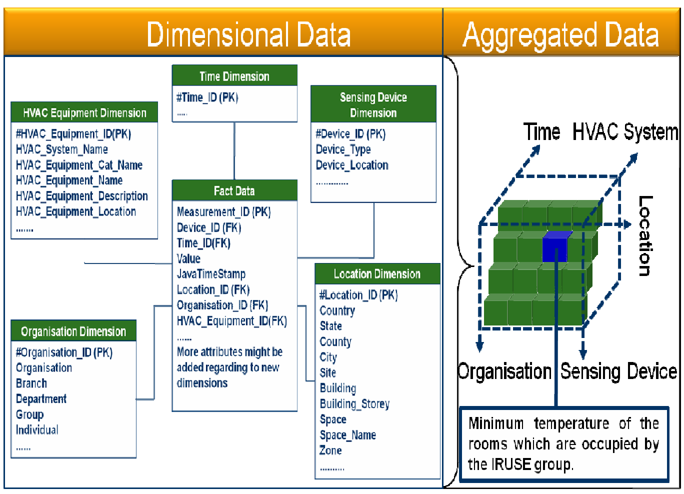

Figure 4: Data Warehouse structure

Figure 4 depicts the proposed data warehouse solution with dimensional data and aggregated data. This dimensional model enables end-users to monitor building performance per room, occupant and HVAC equipment. This gives a broader measure to track the efficiency of specific equipment installed within the building and diagnose performance related issues.

Figure 5 describes the hierarchical structure of HVAC equipment dimension. This consists of the HVAC system information of a particular building. Enables end users to analyse information according to specific HVAC equipment installed in the building, e.g., "return water temperature of the vacuum tube solar collectors."

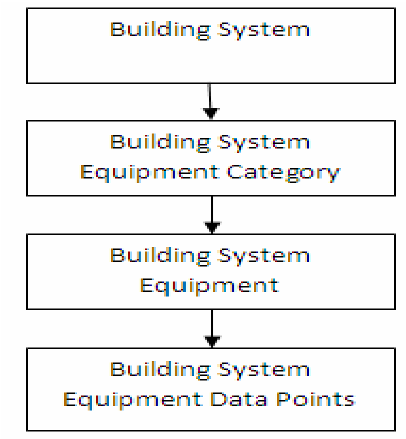

Figure 5: Data Warehouse HVAC Equipment Dimension

3.2.3 Automation of Fault Detection and Diagnosis to Assist Maintenance Operations

Through the use of a data mining methodologies based on building performance history combined with standard performance ratios of facility's plant operation, new maintenance tasks can be generated when the current operation level of a device drops below a specified threshold.

Fault detection involves to collection of defined performance characteristics of equipment and based on current state or the more recent functioning history, a decision needs to taken as to whether the equipment is in a fault state or in need of maintenance. In conventional manufacturing system, pulley devices operate under certain time constraints and their decreasing operational speed may by fixed by a maintenance task of applying lubrication to the faulty joint.

If individual components should attain a fault state, then a diagnosis module calculates the correct maintenance course of action. In the above case of the pulley system the solution is to create a new maintenance task for the faulty equipment using oil or grease inventory. A decision tree can be defined to relate influence factors with performance levels. As decreasing levels of performance introduce more energy deficiency, the replacement of equipment becomes another viable option for consideration.

As there are many influences in this decision making process, over time maintenance history and related performance levels of the equipment can be assessed to produce a more probabilistic answer with the implementation of Artificial Intelligence methodologies such as Fuzzy Logic.

3.2.4 Application of Process Patterns for Specific Maintenance Needs in ARIS EPC Method

With the aid of process patterns the scheduler can produce an insight into how different activities are interrelated and produce a more effective maintenance solution. For this particular building, ERI, the process patterns are provided using ARIS EPC methodology (Scheer 2000).

This methodology was chosen due to its easy to understand notation that is capable of portraying business information systems while at the same time incorporating other important features such as functions, data, organisational structure and information resources.

By using this methodology it is possible to attach documents and codes to the process models. The responsible actors will also be detailed in these models through the use of organisational units. This will allow the maintenance support system to determine the employee skills type required to carry out a particular task. The task template can be evaluated by the predictive maintenance scheduling components and finally be attached to the work schedule.

Maintenance concepts will be split into 4 segments: spare parts needed, equipment needed, required set up, maintenance task / inspection task. It will be composed of the task description and will specify: maintenance ID, expected duration, skills required (i.e. certification of staff), precedence relations. Figure 6 is a sample maintenance process for a geothermal heat pump.

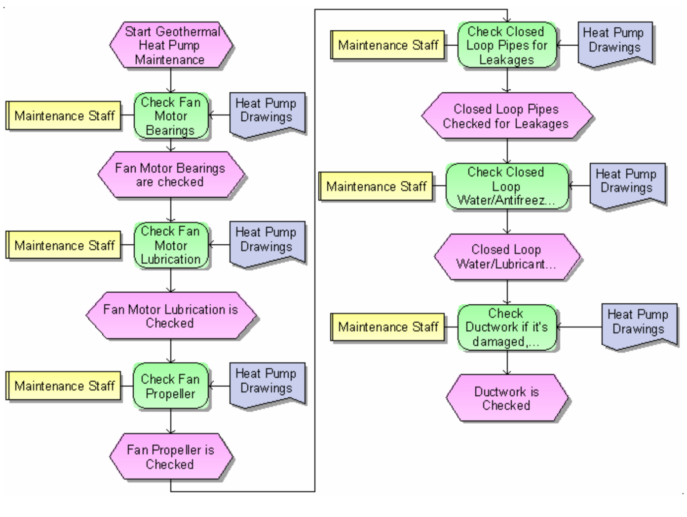

Figure 6: ARIS Business Process Model for Maintenance of Geothermal Heat Pump

3.2.5 *Information Retrieval for Automatic Selection, Distribution and Maintenance of Information for a Specific Task by using Process Patterns*

In this section an initial prototype system to support maintenance procedures is described. In order to explain the steps involved, a geothermal heat pump maintenance task example is demonstrated. The prototype system procedures consist of performance monitoring, diagnostics and maintenance. Firstly, performance monitoring enables end-user to detect performance problems prior to specific building equipment. In our case a decline in the heat output and an increase in electricity consumption of the geothermal heat pump is detected. Secondly, the responsible maintenance staff, which is specified in the ARIS EPC model, is informed to diagnose the problem. Finally, maintenance staff performs the required maintenance activities that are specified with ARIS EPC.

In order to support maintenance activities an inventory tracking system and a GUI have been developed. Spare parts which are critical to equipment operation are stored within facilities. Tracking these parts consists of a basic inventory tracking system. Figure 7 depicts simplified star schema of the inventory tracking database. This enables maintenance staff to track stock availability. It is also possible to integrate this database with the performance monitoring data warehouse system.

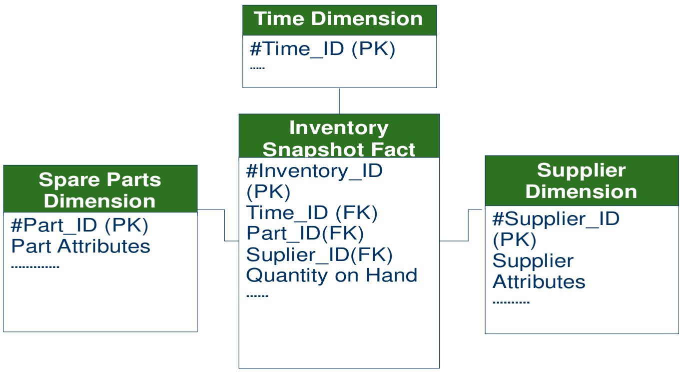

Figure 7: Inventory Tracking Database Schema

Onsite maintenance staff requires support to perform maintenance activities in an effective manner as identified during the maintenance planning phase. In order to achieve critical support for members of the FM team, a mobile device application is developed. Figure 8 depicts the GUI developed for the proposed maintenance system. This GUI retrieves and presents inventory data, ARIS process model for specified maintenance tasks and equipment schematics. Onsite maintenance staff are better equipped to track spare part inventory and to see availability of required spare parts, perform exact maintenance activities as defined with ARIS EPC model and visualise technical drawings for the specific equipments.

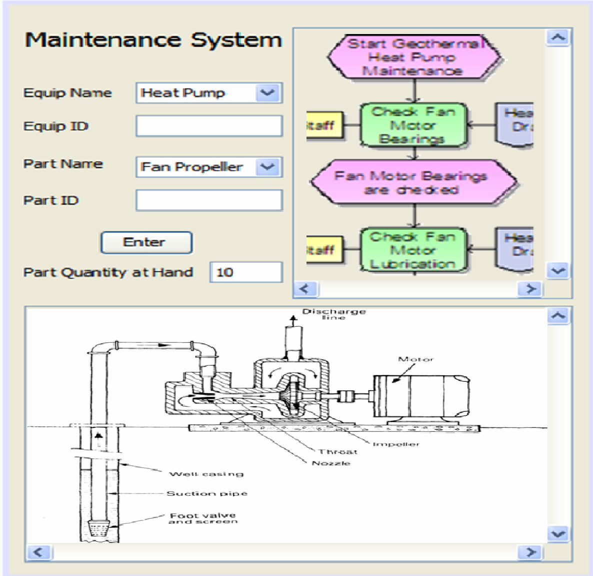

Figure 8: Maintenance Prototype User Interface

4 FUTURE WORK

The next step is to study survey all of the ERI building service components and derive, from manufacturer’s advice and from past experience, a schedule for maintenance activities.

An initial list of plant was compiled from the HVAC systems in the ERI:

1. Flat Panel Solar Collectors
2. Vacuum Solar Collectors
3. Aquifer
4. Heat Pump
5. Gas Boiler
6. Five Air Handling Units and one of which contains heating coils while all contain thermal wheels

For these elements various characteristics can be gauged to create a feasible view of their respective performances. As most of the plant items mentioned are linked with the hot water system in the ERI, monitoring temperatures on specific points of the circuit will provide an effective insight as to the performance coefficients of the individual components. With additional meters energy consumption, and gain from renewable sources, an efficiency rating can be defined relative to performances.

5 CONCLUSION

Our approach is envisioned to deliver maintenance scheduling based on performance analysis allowing optimal usage of components. We are in the initial stages of designing complete process modelling for consistent maintenance scheduling using diverse resources from collaborative networks consisting of multiple companies and we aim to implement complete and consistent technical documentation provision to maintenance crews/technicians from different organisations.

As part of the FM solution it is also proposed that maintenance processes should be adaptable to comply with existing FM standard including the British Institute of Facilities Management (BIFM) and German Facility Management (GEFMA).

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