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MITIGATING CHALLENGES OF MANUAL DATA COLLECTION WITH FIELD FORCE MANAGEMENT INTEGRATION INTERFACE

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Installed base, service base, data collection, field-force management, service base information

Abstract

Product manufacturers can gain significant competitive advantage for their service business by utilizing detailed information about the product individuals that form the installed base or are under service contracts. This Service Base Information includes details on failures and maintenance, location and site, compositional structure, operation and environment, and data for key performance indicators. Information can be collected manually or by automated means. However, 8 cases from Finnish machine building and telecommunications industries indicate that the state-of-the-practice still has significant room for improvement. Quality of manually collected information is low and scope often too narrow. We identify the information needs and describe a proposed OASIS standard – Field Force Management Integration Interface (FFMII). When FFMII is applied with appropriate data content, coding systems, and user interfaces, it is possible to increase the scope and quality of service base information without excessive reporting burden on field engineers. We show how FFMII can be applied to collect necessary information. This, in turn, enables fact-based adaptation of preventive maintenance programs, more efficient field operations, more accurate pricing of service sales, and analysis of field reliability.

1. Introduction

Many manufacturing companies aim to become providers of industrial services. We believe that this transformation can be supported by utilizing detailed information about the product individuals that form the installed base and information that a manufacturer has about products it designed.

Service Base Information (SBI) contains current, historical and future (planned, predicted) information on product individuals that form the installed base and similar information on product individuals manufactured by others but under service. We use the term *product individual* to emphasize that even instances of a product type have own life-cycles and compositional structures.

Service business functions can be efficiently and effectively supported with information that has adequate scope, depth and quality for making decisions. These functions include service operations, service sales (e.g. maintenance contracts, extended warranty, full maintenance), spare part delivery, warranty management, sales of upgrades and modernizations. Furthermore, more strategic benefits may be gained in product and service development..

The scope and quality of manually collected SBI can be improved by developing mechanisms for conveying information from the field in a structured but flexible manner. OASIS committee specification, .i.e. a standard proposal, *Field Force Management Integration Interface (FFMII)* addresses some of the challenges of manually collected SBI. The first and third authors were members of the FFMII technical committee.

This work follows the Design Science approach [Hevner, et al. 2004]. Section 2 identifies business needs by outlining scope and quality requirements of SBI, and the challenging state of the practice. Section 3 depicts the constructed artifact by introducing the basic concepts of FFMII. Section 4 identifies use cases of manual SBI collection, and shows how to apply FFMII to collect the relevant data. To provide a rudimentary evaluation, we show how information needed in a real case could be collected. Finally, Section 5 contains discussion and Section 6 our conclusions.

2. Service Base Information

Required information about installed base covers *item*, *location* and *event information*, each with a number of details [Ala-Risku. 2009]. In our view SBI sometimes covers a wider scope, and also planned and predicted aspects. SBI contains technical (basic information, operational and resource data) and commercial (customer, service contracts, cost, value) points of view. Often SBI is required also on product individuals made by competitors to provide similar support for service operations than for 'own' products. Less details e.g. in terms of structure may be available.

Increasingly, automatic collection of SBI is possible due to advances in state awareness of products and availability of cost-efficient data communications. Furthermore, some SBI is available from operative ICT systems. However, manual data collection is needed for some elements of SBI. For example, only field force can provide many details of preventive and corrective maintenance events.

2.1. What Service Base Information to collect?

As-maintained compositional structure reflects the current compositional structure of a product individual. In the most comprehensive form, the as-maintained structure keeps track of component individuals that occupy each position in a product individual. If this level of detail is not feasible but detailed reliability data is required, timestamps of component changes should be recorded –several performance indicators based on lifetime can be determined. Major component individuals may be tracked and have a life-cycle of their own, e.g. number of refurbishments, successful and unsuccessful identification of faults, etc.

Failure and maintenance data such as those defined in ISO 14224:2006 [ISO. 2006] or a subset may be collected to facilitate analysis of events, their consequences, reasons, and used resources. Maintenance events apply both to preventive and corrective maintenance. Often failure events have corresponding maintenance events. Events form a basis for analysing field reliability, for optimizing preventive maintenance intervals and also for predicting spare part consumption. Examples of data items include failure codes, activity categories, and root cause. Identification data associates events with product individuals or their parts, contains timestamps and identifies involved technicians.

Operational, monitoring and environment data is collected through digitized sources and manual inputs [Dausch, et al. 2006]. Operational data records usage – how and how much. Details may include control and process parameters, startup, shutdown, and idle periods. In the simplest form it may be age or number of usage hours.

Site and location or fleet information describes physical, logical or geographical locations, and is associated with product individuals. Access is important for efficient field operations. It includes access and safety procedures, instructions for reaching the location, contact persons and times of access. Location-related tools may also be included. In our view, also field workers should be able to update location related information.

Service and performance data is collected to compute *key performance indicators* in terms of promises made to customers, e.g. availability and response times. Internally a service provider can follow contract period, costs and utilization of work force. It may also be necessary to collect additional information, such as reasons for occurred SLA (Service Level Agreement) breaches or other exceptions.

2.2. Service Base Information Quality

SBI should have adequate quality for the intended use. [Strong, et al. 1997] identified four *data quality (DQ) categories*, each with a number of dimensions: *Intrinsic DQ* category is direct quality of data independent of use and includes Accuracy, Objectivity, Believability and Reputation. *Accessibility DQ* category consists of Accessibility and Access security. *Contextual DQ* is related to quality of data in given context of use and includes as dimensions relevancy, value-added, timeliness, completeness and amount of data. Finally, *representation DQ* category includes interpretability, ease of understanding, concise representation and consistent representation.

SBI collection by field force has an effect on many of the quality dimensions. Directly dependent dimensions include accuracy, objectivity, timeliness, completeness, concise representation, and consistent representation. Indirectly, impact on believability and reputation is probable.

An assumption is that if field force can easily and with low effort record details at point of maintenance, the quality and timeliness of SBI will increase compared to a situation where such recording is performed only afterwards.

To facilitate interpretability and consistent and concise representation that allows automated analysis, most of SBI should be presented as structured information, and augmented with free form text when needed [ISO. 2006].

2.3. State of the practice

Both previous work and our research in context of 8 cases from Finnish machine building and telecommunications industries shows that the state-of-the-practice of management of SBI has significant room for improvement.

Some manufacturers and their service functions do not know the location of each product individual of the installed base [Dekker, et al. 2012, Jalil, et al. 2010], or if a delivered product individual is still in use. Both these problems are witnessed by some of our industrial cases.

Often, exact as-maintained configurations of product individuals are not known. When third parties or the customer change or modernize a product individual, this information may not reach the original manufacturer [Dekker, et al. 2012]. Even when the manufacturer is the service provider, component changes may not be properly recorded or are only noted as freeform text. Our cases share these problems.

Similarly, maintenance and failure events are not registered or are registered with partial or low-quality information, and the amount of details may not be sufficient. For example in one of our cases about half of failures were classified either as ‘other’ or ‘miscellaneous’.

3. FFMII

Field Force Management Integration Interface (FFMII) was designed to enable communication of Work Requests between *enterprise resource management systems (ERMS)* and *field force management systems (FFMS)* [OASIS FFM. 2012a]. *Manager*, and *Implementation* are respective roles of a software systems that communicate through the FFMII interface. For example, a Manager creates updates, and queries units of Field Work through the FFMII interface. Likewise, an Implementation submits Status Change Notifications and creates Field-Initiated Requests through FFMII. FFMII aims to minimize the time needed to develop, integrate, and deploy field work management solutions [OASIS FFM. 2012b]. FFMII provides a well-founded conceptual basis for modeling and exchange of field work related information, and a corresponding set of calls and associated data structures. We follow the FFMII convention to capitalize each FFMII defined term.

For facilitating structured communication between ERMS and FFMS, FFMII defines mechanisms that enable dynamic Work Request modeling, work history collection, and collection of data from the field. Information carried with Work Requests, Work Request structure (work-flow, schedule) and data to be collected can be defined dynamically as ‘data’. This makes FFMII very flexible and adaptable to different industries and scenarios.

For this paper, the most interesting parts of FFMII are its abilities to collect data from field work, both in context of defined inputs at specific phases of field work, and in context of interactions initiated by the individuals performing field work.

3.1. Conceptual model of FFMII

Main concepts of FFMII are illustrated in Figure 1, using UML notation [OMG. 2003]. A unit of Field Work is modeled as a *Work Request* associated with a *Work Type Specification*. The Work Type Specification specifies a number of *Activities*, their internal work flow, and the structure of associated data content as Data Forms.

Each Activity of a Work Request is performed by one person (*Assignee*). Parallel and/or sequential, Activities within a Work Request are supported. An Activity may be associated with an *Activity Location* and may be constrained by a *Schedule*. For example, a telecommunication installation could have several connection Activities and an installation Activity in corresponding locations.

An Activity is divided into one or more *Steps* that describe the work flow of the Activity. Each Step is associated with a *State* describing the progress of the work (e.g. OnSite, Completed). Each Step may define any number of *Actions* that define the possible transitions from one Step to another.

Activities may have dependencies on State of other Activities – for example to enforce serial execution. It is also possible to enable or disable a specific Action depending on expressions that examine State of a Work Request or values of relevant variables (*Enable Condition*).

Status of an Activity is tracked based on *Status Category* associated with each Step (Open, Active, Inactive, or Closed). Optionally, a Step may be associated with one of the predefined or custom Status Indicators that provide more fine-grained State information, e.g. a State with ‘Active’ Status Category might have Status Indicator ‘EnRoute’ or ‘OnSite’.

Work Request history captures each State transition and user input that occurs during Work Request implementation.

3.2. FFMII mechanisms for collecting data

As primary means of collecting input from the field, an Action may require user input as a *Data*

Form. Next, we introduce concepts necessary to understand Data Forms, the concepts are illustrated in Figure 2.

FFMII supports several *primitive data types* (String, Integer, Double, Decimal, Boolean, Date, Time, DateTime, Duration, and opaque Binary data) and specialized data types such as localized strings and geographic locations. A *Data Field Specification* is based on one of the primitive data types. FFMII also supports two-dimensional *Data Matrixes* where each column is of a primitive type. Furthermore, *Data Attachments* support binary data of any MIME type, e.g. to support PDF documents, vector or raster graphics, and video attachments. Data Fields, -Matrixes, -attachments and -Groups are all *Data Elements.* Their specification includes also information display

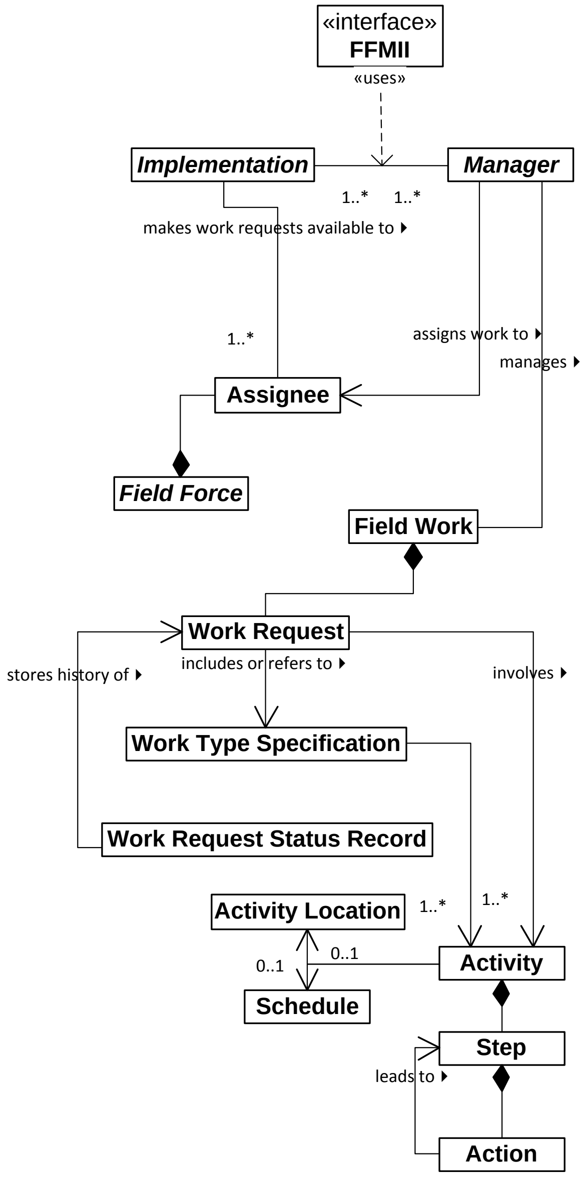

Figure 1 FFMII Domain model, adapted from [OASIS FFM. 2012b]

labels, enumeration of valid answer alternatives or a reference to a separately defined hierarchical selection tree. Furthermore, it is possible to specify the most commonly used input values so that they can be quickly picked from a large number of valid values. A *Data Form* consists of a sequence of Data Elements that can individually be specified as display-only or updateable. For input Data Elements, it is possible to specify hints how to capture the data, e.g. manual entry, scanning barcode, using Radio-frequency identification (RFID), applying satellite navigation system (GPS) or a camera of a portable unit.

It is possible to determine if data input is required based on context and/or previous inputs. *Enable* and *Updateable Conditions* are Boolean expressions whose evaluation specifies if Data Elements are visible and if input is required, respectively. For example, information about a Service level agreement breach is collected if and only if a SLA breach has occurred. FFMII can validate input data with *Validation Conditions,* e.g. by examining State of Activities or other inputs.

Data Forms are also used in *Field-Initiated Request* – requests initiated by an Assignee and dispatched as a structured message. Field-Initiated Requests support requests or reporting outside of the usual work flow such as requesting activation or reset of a product individual, reporting absence, requesting additional work, and identifying a sales lead or an incipient fault.

As a summary, FFMII provides flexible and dynamic means for collecting relevant data that fulfills predefined validation rules.

4. Scenarios of collecting SBI

Next we describe scenarios for collecting information from field work and identify how FFMII can support this. A case illustrates the scenarios.

4.1. Case company overview

A globally operating company ('HMM') designs, manufactures and services power production systems used mainly in ships and power plants. Services of HMM include service calls, installation and commissioning, performance optimization, upgrades, agreements focusing on overall performance, and asset management.

The authors identified field work processes of HMM via interview of HMM process development manager of field services to verify FFMII capabilities. FFMII design was almost complete during interview. Descriptions of HMM case below are adapted from 'Use case 9' of [OASIS FFM. 2012b], and augmented with mapping to capabilities of FFMII.

4.1.1. Work orders

On-call repairs are the most common type of Field Work covering about 80% of work orders. Preventive maintenance (e.g. service, inspection) and troubleshooting are also notable. Major overhauls and commissioning require multiple Assignees with a team leader.

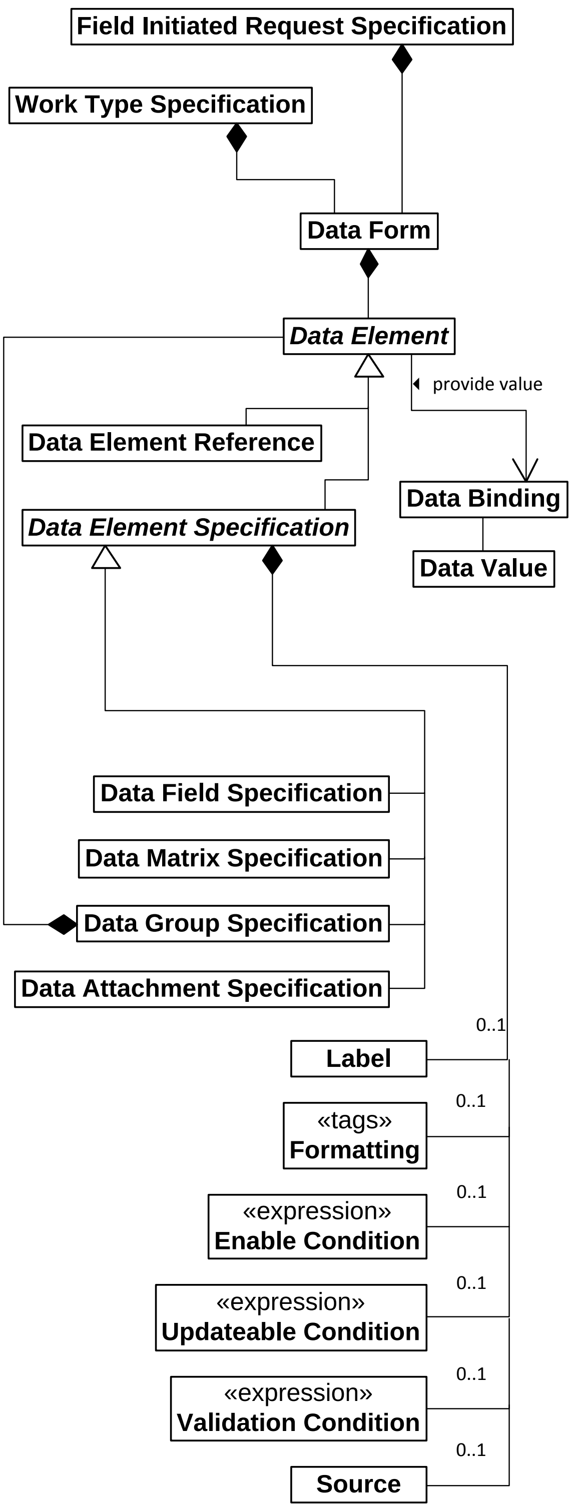

Figure 2: Data Form Data Types, adapted from [OASIS FFM. 2012b]

A work order includes: Order number, Installation number & name, product number, customer number & name, and the task(s) to be completed. Related HMM persons such as a service coordinator, an account manager, and the leading service engineer (if any) are specified. Their contact details, customer contact and location details are provided. In addition, packing lists, a proforma invoice, delivery claim and cargo documents are included. Dependencies between tasks exist – a task must be complete before dependent tasks.

Work orders of HMM fit the design of FFMII. Reusable Work Type Specifications and their State Models can model common work types. Data forms 'Work Overview' and 'Activity Location Data' could include the contact and location details, including any access restrictions, instructions or access procedures. Packing lists, proforma invoice, delivery claim and cargo documents could minimally be e.g. PDF attachments transmitted via Reference Data functionality. Alternatively, Data Forms could be applied for spare part management (Section 4.2).

Some customer locations lack network connections, and the cost of data roaming in some locations is prohibitive. Therefore off-line availability of work orders is important. FFMII has mechanisms that enable off-line progress of Work Requests and recording of inputs, and detection of conflicting (off-line) updates. It is responsibility of Manager to resolve them consistently.

4.1.2. Hours and maintenance times

Some Work Orders have a fixed price or belong to the scope of a service agreement but most work orders are priced on used time (preparation, execution, reporting), spares, and travel costs (time + costs + margin). Sometimes (e.g. off-shore operations) time is reported and charged by a detailed activity type. Upon completion of Field Work, a customer signature confirming time spent is usually required.

Spent hours can be an input Data Field in context of work reporting. Another alternative is to calculate spent time from Work History: When the field service person performs an Action, corresponding State change takes place, and Work History is updated. Work Request Status Record maintains time stamps of transitions.

Therefore it is easy to retrieve spent time for automatic time reporting. If travel Step(s) are included in the state model, travel time can be calculated separately.

Customer signature can be arranged e.g. with digital signature capture of a device or as entry of a separately delivered confirmation code.

An Assignee creates a free-form work order report that may also include internally visible comments. A work report may be modelled as a 'Supplementary Activity' of FFMII, so that it is not tied to any specific phase of the workflow.

Workforce utilization rate is a primary key performance indicator for HMM. Calculation requires recording of all work hours (billed or not, overtime), vacations, and idle time. In principle, it is possible to collect time stamps of beginning and end of work-day, lunch breaks etc. Combined with timestamps of Work Requests, these facilitate automatic calculation of idle time and Work Request related times. Whether this is feasible in practice is a question of future work. As an alternative, Data Forms in field initiated requests defined for time reporting can be applied.

4.2. Update as-maintained configurations and report used spares

Updating as-maintained configurations requires identification of the product individual, optionally identification of position within the product individual, and identification of the replacing component either as a type or as an individual, and a timestamp. Multiple component changes may take place within a service call. Data Forms with position and component identification are applicable. Hierarchical selection trees of FFMII can be used to navigate to the correct position. Time stamps of Actions can provide the time stamps. With the same or additional Data Form(s), the identified spare(s) can be marked to be used e.g. for warranty, to be billed or to be covered by a service contract.

If no automated means of identification are available, the spare part type code is entered manually. If used widely enough, barcode or RFID readers integrated to a portable device can be applied to provide identification of component type or even individual. Alternatively, spare parts used from inventory of the Assignee can be identified with a structured selection tree. For example, the first level would be a device category, the second level a device type, the third level a device model, and the fourth level a replacement part code.

If spare parts are ordered for a specific product individual in advance, background systems can generate content for a Data Form where installation can be confirmed (if necessary individually by component). This can reduce or virtually eliminate effort of the service technician for position and spare part identification.

Sometimes a technician notices that third parties have changed or modified a product individual. Recording such changes involves identifying the modified individual or position within it, and if possible identification of the modification, and possibly an estimate of time of change. The same mechanisms apply as above, except that such a change would probably be recorded as a field initiated request, and only manual data entry would usually be available.

Case HMM. Sometimes an Assignee carries spare parts personally, but usually logistics is separate due to physical size of spares. Usually Field Work starts by checking that all required spare parts have arrived. A listing of expected materials is compared with packing lists of arrived shipment(s). All spare parts ordered for a work order are assumed to be used. Exceptions may occur and are reported. The customer may keep the extra spare parts or they may be sent back.

By converting spare part packing lists into FFMII Data Forms, it would be possible to enable reporting of unused spare parts – by default all parts are marked as used, but they could be marked to be taken to stock by customer, or to be returned. The same form could also be used to report parts missing from the shipment.

4.3. Record maintenance event details

Section 2.1 identified maintenance event and failure data. This data can be collected with Data Forms of FFMII, and validation rules can validate the inputs. Some details such as the root cause may be unknown during field work – such inputs are left out or have a default value of unknown enabling input in case the root cause is known.

Multilevel codes are easy to pick with selection trees. They can also be used to associate failure and maintenance data with product individual, position and/or component individual. Furthermore, Work History records Assignee identity and timestamps.

If necessary, photographs or measurement device output files can be collected as attachments.

Case HMM. Fault coding is relatively systematic during the warranty period. In the current process, a fault location code is recorded by warranty coordinator, not directly by field personnel.

4.4. Record operational and usage data

Operational or usage data may be directly available if product individuals are connected to service provider's systems, e.g. through remote monitoring. Otherwise, field work may involve collecting or downloading usage hours and logs of error codes, alarms and alerts. Sometimes Assignees evaluate environmental conditions or usage profiles so that these can be used in preventive maintenance planning.

Data Forms with product individual identification (Section 4.2) and the relevant information can be used to record operational and usage data.

Relevant examples were not identified at HMM, because the researcher omitted this aspect.

4.5. Record results of inspections and tests

Technical parameters are measured in context of maintenance inspections, tests and major overhauls. They are stored in association with the measured product individual, component individual and/or position in the product. Maintenance inspections also include results of visual and other checks. Data Forms with relevant Data Fields and identification can be applied.

Results of visual inspections include codes and augmenting freeform text. If a recommendation can be determined directly, both structured and free-form input Data Fields can be included.

Similarly, results of periodic condition monitoring activities can be recorded. This may also involve applying devices such as portable vibration analysers. If desirable, it is possible to download such information as attachments of Data Forms.

Case HMM. In inspections and overhauls, ~ 30 technical parameters per engine type (e.g. wear of cylinder liners) are measured and recorded in association with the product individual.

4.6. Record details of installation and commissioning

Basis for SBI may be most efficiently created through back-office operations, but test results and identification of product or component individuals may be collected from the field.

Commissioning includes installation, check, inspection, and test of components and systems. Identification of installed product individual may be connected to a more complex workflow. For example, identification of a cable-tv set top box and a pay-tv card is part of a provisioning process that links them together.

To record changes where as-installed configuration differs from as-designed, Field Initiated Requests with identification of product individual, position and the deviation can be used.

Larger commissioning projects may be relatively unique. Therefore structured definitions of the tasks may not be readily available. This may limit feasibility of FFMII in such contexts.

Case HMM. Commissioning and startup projects are performed by teams with a team leader on site. Management of work via FFMII would not be a priority.

4.7. Record unplanned findings

During field work, an Assignee may identify and consequently report sales leads (e.g. for maintenance inspections, upgrades, preventive maintenance), identify incipient failures, or modifications performed by third parties.

Different types of findings need corresponding Field Initiated Request Topics with related Data Form definitions. The forms would include identification of product individual or site and Data Fields to identify the finding. Based on the Topic, Manager component of FFMII would pass the content to appropriate systems or users.

Case HMM. Opportunities for additional sales of services or products are sometimes identified. These are reported in context of the product individual or site so that the account manager can contact the customer. With FFMII, these sales leads would be routed into the CRM system.

4.8. Update compatible spares

Compatible spare parts may change due to modernisation, upgrade or overhaul. E.g., a motor is modified to use oversize cylinder liners to compensate for wear. Often, it is more efficient to perform such updates as back-office operations. When spares change as result of field work, it is possible to create Data Forms with position identification and appropriate data content.

Case HMM. Each product individual has compositional structure that records compatible spares. These may change at product individual level. Customers or competing service providers may install third party spare parts or modify the product individual. Reporting these fluently via FFMII could make it more likely that these findings are recorded. Because a product individual consists of about 3000 material numbers, hierarchical selection lists would be of use.

5. Discussion

Despite developed technical support, manual data collection is challenging. Motivational and organizational factors are as important as technological solutions. Data collectors should be aware of why data is collected and what benefits can be gained by better manual data collection.

Careful analysis of what information to collect is required – excessive reporting burden that slows down field work processes is undesirable.

Previous work identified a case in military aviation, where data collection at point-of-maintenance did not improve quality of collected data [Cone. 2006]. However, data collection equipment suffered from poor data connections and slow performance. In our view, this emphasizes that the whole process must be fluent from the point of view of field force. Our view is that it would be beneficial to involve real users in the spirit of user-centred design into the process of designing the user interfaces for data collection.

5.1. On technical aspects of implementation

FFMII does not remove challenging system integrations. However, it provides a well-founded conceptual basis for modelling Field Work and specifying data to collect. Furthermore, FFMII defines a concrete machine-readable way of transmitting and collecting this data. This protocol binding is based on XML and SOAP based web services that are often used in system integrations. As a whole, FFMII provides a solid foundation for designing and implementing systems that are based on flexible modelling of data and processes, in addition to providing a standardized interface for integrating these systems.

One of the challenges in putting together a complete field work management solution is that many existing products use quite rigid data models and process flows. This does not only make it difficult to adapt data and state information between different systems but it also makes it very challenging to adapt these products for new types of use cases.

The flexibility offered by the FFMII model may also provide new possibilities for individual deployments. For example, as it becomes simpler and more cost efficient to modify the existing work order structure it may become feasible to experiment with new ideas and potential enhancements. The end users also benefit from data and process model that more closely matches their needs. On the other hand, all optional features of FFMII are not required in all deployment contexts, which may allow simpler implementations. For example, if the set of work request types is genuinely stable, simpler implementations may rely on a fixed set of Work Request types instead of dynamically defined ones.

To collect coded data items from field work via FFMII, corresponding Data Elements, valid answers and desired validation rules must be defined and associated with FFMII objects. Information systems such as ERMS must have locations to store the answers. Some systems may be flexible enough and have appropriate scope while others may not. For example, some maintenance management systems record timestamps for changes of individual components only for components that are tracked individually. Therefore storing information for calculation of field reliability for an extended set of components might bear challenges.

An example of the underlying complexity is out case company. HMM processed Work Orders in SAP ERP. Therefore an adapter that provides FFMII Manager functionality in this context would be needed. However, integrating with ERP is not enough: some information from Field Initiated Requests or Work Requests needs to be forwarded from the Manager to systems that actually process or store it. These systems may include technical data databases (e.g. measurements), maintenance management systems (e.g. maintenance event details), and CRM (e.g. sales leads). Further integration needs may originate from providing Assignee information, relevant work instructions, etc.

Care is needed in defining a sufficient but maintainable set of FFMII Work Order and Field Initiated Request types and their information contents. An excessive set of types may be difficult to keep up-to-date, and could also confuse field workers.

ERMS and FFMS vendors, their partners and third parties may be developing FFMII Manager and Implementation modules, but currently the availability of FFMII compliant systems is limited.

In practice most currently available products would require an external interface layer to act as an FFMII Manager or Implementation. The full benefits of FFMII are realized only if ERMS and FFMS vendors start supporting it as part of their standard product lines.

6. Conclusions

We identified scope and challenges of service base information. FFMII provides a conceptual basis and concrete data exchange protocol for structured information exchange between Field Force Management and Enterprise Resource Management. FFMII was designed to be flexible to be applicable in various use cases. We conducted lightweight validation of FFMII applicability by analysing how data could be collected from field work of a major machinery manufacturer. Applicability seems promising.

When FFMII is applied with appropriate data content, coding systems, adequate user interfaces and organizational and motivational support, we believe that it is possible to increase the quality of service base information without creating excessive reporting burden for the Field Force.

Potential data quality improvements include more accurate information about required effort of different tasks (maintenance times), improved as-maintained product structures, and more accurate failure and maintenance data. Together, these enable fact-based decision making that has potential to lead to more efficient and effective services e.g. through adaptation of preventive maintenance programs and, through input to product development, also improved products.

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