Applying Capability Maturity Model for Maintenance Services: A Case Study

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Abstract

The objective of this paper is to present a systematic approach for evaluating and appraising maintenance. In order to study maintenance as a service, we have adopted the Capability Maturity Model Integration for Services, (CMMI-SVC, V1.2), which has been designed for and implemented mainly on Information Technology (IT) Services. CMMI-SVC, V1.2 is a CMMI variant and it contains twenty four process areas, where seven are service specific. These are: a) Service Delivery, b) Capacity and Availability Management, c) Incident Resolution and Prevention, d) Service System Transition, e) Service Continuity, f) Service System Development, and g) Strategic Service Management. CMMI is structured around maturity levels, where each level is defined by the set of implemented processes. CMMI defines five levels of organizational maturity, starting from level one which is defined as chaotic and ad-hoc and reaching to level five, which is the ideal state, where each process is measured and optimized.

In the presented case study, the maintenance processes of a major Greek food company have been assessed, in order to evaluate the maintenance maturity according to CMMI-SVC, V1.2. Consequently, the maintenance processes have been re-engineered and restructured according to the process areas and the best practices presented in CMMI-SVC, V1.2, in an attempt to evaluate if maintenance is profited by practices presented in the IT service model.

Keywords: maintenance, service management, maturity model, Greece.

1. Introduction

Modern industries are characterised by their dependency on technology for the production of products and services. Every business needs equipment to produce and deliver its outputs and it is a crucial asset for business success in an intensely competitive global market. However, the rapid evolution of technology during the last years has led to the development of more complex equipment and as a result the economic use of plants and equipment is of major importance for achieving a cost-efficient production process, which in turn mainly depends on
the proper condition of production machineries, thus introducing the importance of maintenance in modern industry (Murthy et al., 2002; Cooke, 2003). As a result, research (Mitchell et al., 2002; Bardey et al., 2005) concludes to the fact that maintenance has an important role directly related to the competitiveness and operational performance of businesses and that should be considered as part of their strategy. An effective maintenance operation reduces breakdowns of production equipment, hazards for the product and the operators, reduces the cost of production and improves the quality of final product or service, thus providing a competitive advantage to the company (Pintelon et al., 2006).

The above notions introduce the concept of performance appraisal as a key factor for controlling and improving the maintenance operation, both from the perspective of management and that of individuals (Parida and Kumar, 2006). In the presented case study, the maintenance processes of a major Greek food company have been assessed, in order to evaluate the maintenance maturity according to CMMI-SVC, V1.2. Consequently, the maintenance processes have been re-engineered and restructured according to the process areas and the best practices presented in CMMI-SVC, V1.2, in an attempt to evaluate if maintenance is profited by practices presented in the IT service model. More specifically, this paper attempts to give answer to the question, if a model such as CMMI-SVC, V1.2 initially designed for IT services can be used for maintenance services in the general case.

The remaining of the paper is structured as follows: chapter 2 presents the research background, chapter 3 the research design, chapter 4 the research results and finally chapter 5 the conclusions.

2. Research Background

Any maintenance strategy needs to be effective in order to obtain the company’s strategic objectives. An effective maintenance strategy is one that fits the needs of the business and its performance is judged based on certain measurable criteria (Pintelon et al., 2006). Therefore, it becomes more than obvious that maintenance performance should be measured in order to support and improve the company’s success and survivability (Parida and Kumar, 2006). There are several approaches of maintenance performance measurement. Cooke (2003) assesses the maintenance strategies of selected industries and their adopted maintenance policies. He defines potential problems that restrain the application of more effective maintenance policies and recommends some management practices that could aid their
implementation. Silva et al. (2008), support their findings on indicators, based on mathematics, related to cost efficiency of selected maintenance policies. Sherwin (1999) audits maintenance policies, in order to estimate the rate of failures, which is then used for the evaluation of cost and savings by implementing the audited maintenance policies. Yam et al. (2000) study the enhancement of maintenance management performance through benchmarking. The main difficulty is that benchmarking with direct competitors is difficult since it involves the sharing of sensitive information.

Beside the above approaches, the concept of Overall Equipment Effectiveness (OEE) is traditionally used by manufacturing companies to measure the effectiveness of maintenance (Parida and Kumar, 2006). Its calculation contributes three major sectors of the production process: maintenance, production and product quality (Tsarouhas, 2007; Ben-Daya and Duffuaa, 1995). The attendance of each has been quantified and they are all expressed by the following indicators:

- Availability,
- Performance efficiency and
- Quality rate (Tsarouhas, 2007).

The multiplication of the three above indicators determines the OEE that globally expresses the production lines effectiveness (Tsarouhas, 2007; Ben-Daya and Duffuaa, 1995):

$$OEE = Availability \times Productivity\ efficiency \times Quality\ rate.$$  

All the above methods provide useful information for maintenance performance but they only measure the internal effectiveness of maintenance, which deals with the way of doing things right. Maintenance performance measurement, however, should include both internal and external effectiveness, with external effectiveness reflecting the customer satisfaction and the growth in market share. The performance measurement for external effectiveness deals with measures that have long term effect on companies’ profitability and it is characterized by delivering right type of maintenance services according to the customer will (Parida and Kumar, 2006). Therefore, maintenance performance could be measured as an overall service with main objective to satisfy its stakeholders’ goals.

Research has approached that direction of maintenance performance measurement with Pintelon et al. (2006) adapting the Hayes and Wheelwright’s four-stage framework on manufacturing strategy as a guide to develop a similar one for maintenance strategy. Their attempt, based on empirical case studies, aims at establishing evaluation guideline system for plant maintenance and it mainly measures its internal effectiveness.
Liu and Yu (2004) evaluate the relative efficiency of plant maintenance by using a method based on Data Envelopment Analysis (DEA). Their method processes maintenance as a service system and provides measurable criteria for assessing mainly internal effectiveness of maintenance, including profits and equipment effectiveness. Their developed model is quite complicated and requires at least two production units of the same plant in order to get some results through comparison.

Other approaches to performance measurement and improvement that the literature offers in abundance are those of business process re-engineering, benchmarking, continuous improvement and many other approaches of modern management (Zairi, 1997). One thing which is noticeable, however, is the growing usage of the word “process” in business language. This suggests that many organizations adopt a process-based approach to manage their operation and that business process management is a well established concept (Zairi, 1997).

A process is an approach for converting inputs into outputs (Zairi, 1997; Damij, 2007). It is the way in which all the resources of an organization are used in a reliable, repeatable and consistent way to achieve its goals (Zairi, 1997).

2.1 Use of service-focused models and standards
The last presented notions provide the initiative to approach maintenance as a service and appraise its effectiveness, by focusing on its processes. In order to do so, it is necessary to adopt an already developed framework.

Thus, another possible approach to maintenance performance measurement could be the adoption of a service-focused model, such as the CMMI-SVC, V1.2 (CMMI for Services, Version 1.2, 2009), which is a model for process improvement through collection of best practices. In this way maintenance could potentially be confronted as a service and its performance measurement could be based on the appraisal of its developed or not processes. There is no evidence found in literature, neither similar researches to adapt CMMI-SVC, V1.2 on maintenance in order to provide results for discussion and comparison. However, “service is a means of delivering value to customers by facilitating outcomes customers want to achieve without the ownership of specific costs and risks” (Best Management Practice, 2009) and since maintenance meets that definition it could be doubtless described as a service provider giving the initiative for applying it on such model.
2.2 CMMI-SVC, V1.2 presentation

CMMI (Capability Maturity Model Integration) models are collections of best practices that help organizations to improve their processes. There are several models that have evolved and one of those is the CMMI for services, version 1.2 (CMMI-SVC, V1.2). It is an evaluation model defined in levels that allows best practice implementation to be consistently applied and incorporates processes which can be measured and monitored aiding management of an organization (CMMI for Services, Version 1.2, 2009).

CMMI-SVC, V1.2 does not specify that a project or organization must follow a particular process flow or that a certain number of services are delivered per day or specific performance targets are achieved, but only that there are processes in place for adequately addressing service related practices (CMMI for Services, Version 1.2, 2009).

All CMMI-SVC, V1.2 model practices focus on the activities of the service provider. Seven process areas focus on practices specific to services, addressing capacity availability and management, service continuity, service delivery, incident resolution and prevention, service transition, service system development and strategic service management processes (CMMI for Services, Version 1.2, 2009).

CMMI-SVC, V1.2 consists of:

- **Process areas and their associated goals.** A process area is a set of related activities that when implemented collectively can achieve the stated goals for that process area, which are regarded important in order to make improvement in that area.

- **Specific and generic practices.** A specific practice is a description of an activity that is considered important in achieving the associated specific goal. A generic practice is a practice that applies to multiple process areas and describes an activity that is considered important in achieving the associated generic goal.

- **Capability and maturity levels.** Capability levels apply to an organization’s process improvement achievement in individual process areas. These levels are a means for incrementally improving the processes corresponding to a process area. There are six capability levels numbered 0 through 5. Maturity levels apply to an organization’s process improvement achievement across multiple process areas. These levels are a means of predicting the general outcomes of the next project undertaken. There are five maturity levels numbered 1 through 5 (CMMI for Services, Version 1.2, 2009).

The maturity levels refer to the overall maturity of the organization and whether individual processes are performed or not is not the main focus. The maturity levels are measured by the achievement of the specific and generic goals associated with each predefined set of process
areas (CMMI for Services, Version 1.2, 2009). A presentation of the maturity levels is provided on Table 1.

Table 1. Presentation of maturity levels

<table>
<thead>
<tr>
<th>Levels</th>
<th>Staged Representation - Maturity Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1</td>
<td><em>At initial level</em>, processes are usually ad hoc and chaotic. Success depends on the competence and heroics of people in the organization and not on proven processes.</td>
</tr>
<tr>
<td>Level 2</td>
<td><em>At managed level</em>, projects, processes, work products and services are managed and processes are planned in accordance with policy. Process performance is measured and analyzed and processes are periodically monitored and controlled.</td>
</tr>
<tr>
<td>Level 3</td>
<td><em>At defined level</em>, service providers use defined processes for managing projects. A defined process clearly states the purpose, inputs, activities, roles, measures, verification steps and outputs.</td>
</tr>
<tr>
<td>Level 4</td>
<td><em>At quantitatively managed level</em>, service providers establish quantitative objectives for quality and process performance and use them as criteria in managing processes. Quality and process performance are understood in statistical terms.</td>
</tr>
<tr>
<td>Level 5</td>
<td><em>At optimizing level</em>, service providers focus on continually improving process performance through incremental and innovative process and technology improvements that enhance providers’ ability to meet their quality and process performance objectives</td>
</tr>
</tbody>
</table>

(Source: CMMI for Services, Version 1.2, 2009)

CMM-SVC, V1.2 describes 24 process areas. Table 2, summarises these process areas and their associated purposes and maturity levels.
Table 2. Process Areas and their associated purposes and maturity levels

<table>
<thead>
<tr>
<th>Process Area</th>
<th>Maturity Level</th>
<th>Purposes of process areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity &amp; Availability Management (CAM)</td>
<td>3</td>
<td>To ensure effective service system performance and ensure that resources are provided and used effectively to support service requirements.</td>
</tr>
<tr>
<td>Causal Analysis &amp; Resolution (CAR)</td>
<td>5</td>
<td>To identify causes of defects and problems and take action to prevent them from occurring in the future.</td>
</tr>
<tr>
<td>Configuration Management (COM)</td>
<td>2</td>
<td>To establish and maintain the integrity of work products using configuration identification, control, status accounting and audits.</td>
</tr>
<tr>
<td>Decision Analysis &amp; Resolution (DAR)</td>
<td>3</td>
<td>To analyze possible decisions using a formal evaluation process that evaluates identified alternatives against established criteria.</td>
</tr>
<tr>
<td>Integrated Project Management (IPM)</td>
<td>3</td>
<td>To establish and manage the project and the involvement of relevant stakeholders according to a defined process that is tailored from the organization’s set of standard processes.</td>
</tr>
<tr>
<td>Incident Resolution &amp; Prevention (IRP)</td>
<td>3</td>
<td>To ensure timely and effective resolution of service incidents and prevention of service incidents as appropriate.</td>
</tr>
<tr>
<td>Measurement &amp; Analysis (MA)</td>
<td>2</td>
<td>To develop and sustain a measurable capability used to support management information needs.</td>
</tr>
<tr>
<td>Organizational Innovation &amp; Deployment (OID)</td>
<td>5</td>
<td>To select and deploy incremental and innovative improvements that measurably improves the organization’s processes and technologies.</td>
</tr>
<tr>
<td>Organizational Process Definition (OPD)</td>
<td>3</td>
<td>To establish and maintain a usable set of organizational process assets and work environmental standards.</td>
</tr>
<tr>
<td>Organizational Process Focus (OPF)</td>
<td>3</td>
<td>To plan, implement and deploy process improvements, based on an understanding of current strengths and weaknesses of the organization’s processes.</td>
</tr>
<tr>
<td>Organizational Process Performance (OPP)</td>
<td>4</td>
<td>To establish and maintain a quantitative understanding of the performance of the organization’s set of standard processes in support of achieving quality and process-performance objectives.</td>
</tr>
<tr>
<td>Organizational Training (OT)</td>
<td>3</td>
<td>To develop skills and knowledge of people so that they can perform their roles effectively and efficiently.</td>
</tr>
<tr>
<td>Project Monitoring &amp; Control (PMC)</td>
<td>2</td>
<td>To provide an understanding of the project’s progress so that appropriate actions can be taken when the project’s performance deviates significantly from the plan.</td>
</tr>
<tr>
<td>Project Planning (PP)</td>
<td>2</td>
<td>To establish and maintain plans that define project activities.</td>
</tr>
<tr>
<td>Process &amp; Product Quality Assurance (PPQA)</td>
<td>2</td>
<td>To provide staff and management with objective insight into processes and associated work products.</td>
</tr>
<tr>
<td>Quantitative Project Management (QPM)</td>
<td>4</td>
<td>To quantitatively manage the project’s defined process to achieve the established quality and process-performance objectives.</td>
</tr>
<tr>
<td>Requirements Management (REQM)</td>
<td>2</td>
<td>To manage requirements of the project’s products and to identify inconsistencies between those requirements and the project’s plans and work products.</td>
</tr>
<tr>
<td>Risk Management (RSKM)</td>
<td>3</td>
<td>To identify potential problems before they occur, so that risk-handling activities can be planned and invoked as needed.</td>
</tr>
<tr>
<td>Supplier Agreement Management (SAM)</td>
<td>2</td>
<td>To manage the acquisition of products and services from suppliers.</td>
</tr>
<tr>
<td>Service Continuity (SCON)</td>
<td>3</td>
<td>To establish and maintain plans to ensure continuity of services during and following any significant disruption of normal operations.</td>
</tr>
<tr>
<td>Service Delivery (SD)</td>
<td>2</td>
<td>To deliver services in accordance with service agreements.</td>
</tr>
<tr>
<td>Service System Development (SSD)</td>
<td>3</td>
<td>To analyze, design, develop, integrate, verify and validate service systems, so as to satisfy existing or anticipated service agreements.</td>
</tr>
<tr>
<td>Service System Transition (SST)</td>
<td>3</td>
<td>To deploy new or significantly changed service system components while managing their effect on ongoing service delivery.</td>
</tr>
<tr>
<td>Strategic Service Management (STSM)</td>
<td>3</td>
<td>To establish and maintain standard services in concert with strategic needs and plans.</td>
</tr>
</tbody>
</table>

(Source: CMMI for Services, Version 1.2, 2009)
3. Research Strategy

The objective of this paper was to study maintenance as a service in order to appraise its total effectiveness, by using CMMI-SVC, V1.2 model. The above objective, however, generated two research questions, which are described below:

Q1: Could CMMI-SVC, V1.2 model be used for assessing maintenance maturity in the general case?

The selected model describes a series of process areas which refer to service establishment and delivery, project management and support and all or some of them should be present on an organization providing service. The research should prove if it is possible to effectively adapt the SMMI-SVC model to maintenance processes or not.

Q2: Could maintenance be profited by practices presented in the IT service model CMMI-SVC, V1.2?

Since CMMI-SVC, V1.2 could be adapted to maintenance, the research should examine if the model under investigation provides a more effective way to measure maintenance performance or the existing is already efficient, or even better. Moreover, the research concluded to the benefits that maintenance could potentially gain from the CMMI-SVC, V1.2 model and how these could aid to improve its overall performance.

In order to approach the above described research questions the case study approach was adopted, since it has been widely used in the studies of organizations, generating a huge amount of quality information that help to better understand their operation in reality (Cooke, 2000). Moreover, maintenance operation comprises of technological change, organizational change and skills, which are by their nature complicated issues, interrelated to each other and therefore, a comprehensive research method is required in order to capture different aspects of the issues under research.

3.1 Presentation of the company

The pasta production company of the case study, denoted as company “A” from now on, is a leading company in its business in Greek market. The plant is fully automated in its whole process and employs approximately 120 persons.

Due to the kind of its products, production equipment needs to operate continuously, when it is scheduled to do so. Most types of pasta can not remain more than 30 minutes in a stagnant production line, otherwise pasta does not meet the strict quality standards and it is wasted.
with obvious negative economic results. Therefore, the maintenance operation is of great importance for the company.

Maintenance department employs 11 full time persons in total. A mechanical engineer is in charge of the department with one chief mechanic, one chief electrician, two electricians and six mechanics comprising the department’s work force. Maintenance operates in three shifts, supporting the production process continuously.

3.2 Research design

In order to answer the first question the existing activities and processes of the maintenance department needed to be identified and defined. Thus, documentation such as objectives and measurable goals of the maintenance department and description of its processes needed to be collected.

The collection of data was followed by a presentation of the maintenance processes. These processes, however, needed to be presented in a formal way that could be easily understood by the reader and adapted to the CMMI-SVC, V1.2 model. For that reason, it was regarded helpful to adopt and utilize a business process modeling tool.

The potential use of Event Process Chains (EPCs) seemed to be useful to represent maintenance processes. Microsoft Visio was chosen, because it provides the ability to draw an EPC flowchart, it is easily downloaded, without any restrictions and required licenses and it is compatible with the rest of the Microsoft utilities that are used by the author in order to complete that study. Figure 1 presents the symbols used in the research for maintenance process modeling.

Figure 1. Symbols used in the research for the maintenance process modeling.

Once the maintenance process modeling was done, the next step was to compare the maintenance processes with the corresponding process areas described by CMMI SVC, V1.2,
so as to justify the possibility of adapting the model to maintenance. An examination of their similarities and differences was the following step in order to correlate them.

The desired maturity level that could potentially be achieved by maintenance was then selected and its related process areas were presented by using again Microsoft Visio, and followed by a potential adaptation of maintenance to those process areas of the selected maturity level.

This was then followed by a comparison of the current performance measurement method with the future potential application of the model in order to detect the differences as well as the benefits gained by potentially applying CMMI SVC, V1.2 on maintenance.

4. Research results

4.1 Description of current condition

Maintenance department has set three main objectives in order to regard its function successful:

1. The first objective is to continually support the company’s main business objective which is the effective and efficient production of high and standardized quality pasta products.
2. Secondly, to maintain the equipment as to maximize the Return Of Investment (ROI) through maximizing their effective utilization.
3. Thirdly, to provide a safe operating environment for the company’s operators, in order to avoid labor accidents.

In order to achieve the above stated main objectives, the maintenance department defined some processes and activities, which are presented below, on Table 3.

Table 3. Summary of maintenance processes and activities

<table>
<thead>
<tr>
<th>Maintenance processes</th>
<th>Maintenance activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Maintenance Requirements Definition</td>
<td>Corrective Maintenance Implementation</td>
</tr>
<tr>
<td>2 Maintenance Capacity and Facilities Management</td>
<td>Condition Based Maintenance Implementation</td>
</tr>
<tr>
<td>3 Preventive Maintenance Planning and Implementation</td>
<td></td>
</tr>
<tr>
<td>4 Projects Planning and Control</td>
<td></td>
</tr>
<tr>
<td>5 Maintenance Performance Measurement</td>
<td></td>
</tr>
<tr>
<td>6 Personnel’s Training</td>
<td></td>
</tr>
</tbody>
</table>
The maintenance processes are series of actions, events and decisions that are done to achieve a particular result, while the maintenance activities are actions driven by events or decisions. The application of the above processes and activities affects not only the achievement of the department’s main objectives, but also the interrelationship of themselves. The interactions among them are illustrated below, on Figure 2.

**Figure 2. Dependencies and Interactions of Maintenance Processes and Activities**

Each box on Figure 2 represents a maintenance process or activity. Their implementation results in several outcomes, which are represented by the curved arrows, and they operate as
inputs on other processes or activities. These inputs take the form of an information or maintenance results with real or potential effects on affected processes and activities.

4.2 Discussion on the proposed model
The research results of that study indicate that the CMMI-SVC, V1.2 model could be adopted by the studied maintenance department. There are existing conditions to permit its application and some of the process areas are already applied. In order to adopt and implement the model evenly, the maintenance department could set as its first objective to achieve maturity level 2 on the short run and become an effective service provider operating with discipline, where projects, processes and services are managed. In order however to achieve maturity level 2 the department needs to apply all process areas referring to that maturity level, namely COM, MA, PP, PMC, PPQA, REQM, SAM and SD. Each one of the above process areas is presented and discussed in the following paragraphs and additional actions are proposed for the improvement of their implementation by the maintenance department. The model’s described practices that are adopted by maintenance are illustrated by a green rectangle, while those not adopted are illustrated by a red rectangle.

Configuration Management process area
The purpose of Configuration Management (COM) process area is to establish and maintain the integrity of work products using configuration identification, control and audits. The work products placed under configuration management include the services that are delivered to the customer, the internal work products and the acquired materials and tools used in creating these work products (CMMI for Services, Version 1.2, 2009). Figure 3a illustrates the Specific Goals (SGs) of the COM process area and the Specific Practices (SPs) for achieving them, while Figure 3b illustrates how that process area could be applied on the maintenance department of the case study.
For the maintenance department, items under configuration management include requirements specifications and interface documents. The plant’s equipment is supported by a series of technical publications explaining the installation, the operation, the adjustment and the preventive maintenance of the equipment. All these documents should be given a unique identification number and should be placed in identified folders with their important characteristics being specified. Up to now, this work is partially done by the department’s managers and therefore the retrieval of documents when required is quite confusing and time-consuming.

The above work could also be applied to the general case of maintenance operation. The construction of a database could be proved very useful, and it could be separated in folders providing information on the following matters:

- Guidance for searching on the printed material that helps personnel to avoid disarrangement of a series of documents in order to retrieve what is looking for.
- The basic information required for scheduling and conducting preventive maintenance.
- Spare parts and tools could be configured and could be kept on that database, so that their position can easily be traced.
- Description of the processes and activities of the maintenance department.
Since the configuration identification is properly done, the next step is to establish a mechanism to manage this database. Recurring information from the technical manuals, for instance, must be controlled and there must be a defined level of control for its access by the personnel.

Yet, the configured materials should be controlled for any modifications and changes that take place. An electrical modification, for instance, should be revised on the corresponding drawing and a change on the preventive maintenance schedule (e.g. the replacement of a type of lubricant) should be revised on the corresponding maintenance instructions.

Finally, configuration audits should be performed in order to confirm the configuration integrity. Some sub-practices could be to:

- Confirm that the configuration management records correctly identify configuration items. This could be performed directly from the maintenance manager to audit consistency and accuracy of his department’s configuration management.
- Review the structure of items in the configuration management system.

**Measurement and Analysis process area**

The *Measurement and Analysis* (MA) process area is well designed and implemented. The main reason for that is that it is the only way to prove the benefits provided to the company by the department’s operation. Figure 4a illustrates the SGs and SPs described by the model, while Figure 4b illustrates the current situation enriched with new proposed sub-practices so as to improve the process.

New objectives could be added on that process, relating to the quality of the service. A questionnaire could be handed out once per year and answered by the production departments personnel asking for their view on the service quality of maintenance. This activity could indicate lack of team-working or motivation or unaccepted behaviors which could be improved through training and development. The defective productions due to deficient or ineffective maintenance or due to equipment breakdowns could also be set as a measurable objective. The last is already recorded and analyzed, but it has not been set as a measurable objective yet.
The enrichment of MA process with these new objectives will improve the maintenance service, by rendering maintenance responsible not only for the technical and economical performance of the plant, but also for quality provided to the internal customers and final consumers.

**Project Planning process area**

Project Planning (PP) is a process area that is well designed and implemented by the maintenance department. It is used on several projects referring to overhauls and new machineries installation. The complexity and size of the projects vary and could be quite
simple and frequently planned and implemented or complex and long-lasting, such as the erection of a new production line.

Figure 5a illustrates the PP process as described by the CMMI-SVC, V1.2 model, while Figure 5b illustrates the current process followed by the maintenance department of the case study.

Figure 5a. PP Process Area

Figure 5b. Maintenance PP

(Source: CMMI for Services, Version 1.2, 2009)
The specific goals and practices that the model describes are followed by the maintenance department and are the establishment of estimates, the development of a plan and the obtainment of commitment to the plan. The following steps are taken every time a project is planned:

- Definition of the project strategy.
- Development of Work Breakdown Structure (WBS).
- Cost estimation
- Development of project budget and project schedule.
- Identification of project risks and risk evaluation.

Since the maintenance PP design and implementation matches the model’s description, the authors believe that there is no reason for any alterations. More effective practices could be adopted through experience in the future.

**Project Monitoring and Control process area**

Project Monitoring and Control (PMC) is again a process area adopted and well developed by the maintenance department of our case study. The CMMI for Services model proposes that one specific goal should be to monitor the project against the plan and the second goal should be to manage corrective actions when the results or the performance deviate significantly from the plan (CMMI for Services, Version 1.2, 2009). Figures 6a and 6b illustrate the SGs and SPs that the model defines and the current process that is followed, respectively.
Specific practices being followed by the maintenance department include the monitoring of:

- the project’s planning parameters
- project risks
- stakeholder involvement
- the monitoring of progress and
- milestones reviews.

Whenever corrective actions need to be taken, the potential alternatives are listed and analyzed with the participation of the relevant stakeholders, such as the plant manager,
technicians, external cooperators and so forth. The corrective action is then recorded and its result is recorded for future similar requirement.

Similarly to the PP process, the PMC design and implementation matches the model’s description and thus there is no reason for any alterations. Again, more effective practices could be adopted through experience in the future. It should be mentioned however that the maintenance department of the case study has embodied the two processes into one and calls it Project Planning and Control, as stated on chapter 4.1. Their separation could help on better controlling and improving the processes and moreover it is a prerequisite for adopting the model.

**Process and Product Quality Assurance process area**

Process and Product Quality Assurance (PPQA) is a process area that has never been followed formally by the maintenance department. Even if there is a Quality Assurance department and a growing quality culture in the company of the case study, the quality of maintenance services is difficult to be judged by another independent department and up to now it is not. Figure 7a illustrates the model’s definition of that process area, while Figure 7b is a proposal of goals and practices that the maintenance department could adopt and implement in order to apply PPQA.

![PPQA Process Area](Source: CMMI for Services, Version 1.2, 2009)

![Future Maintenance PPQA](Source: CMMI for Services, Version 1.2, 2009)
Another approach to quality assurance could be the parallel implementation of the service and its quality assurance (CMMI for Services, Version 1.2, 2009). The maintenance department could control if the implementation of its projects and activities complies with the corresponding procedures that the department has already set, through its processes.

Such a situation, however, contains some risks. The first is that of selecting the persons to perform the quality assurance role. The specific role requires training and those people performing quality assurance should participate in establishing plans, processes, standards and procedures to ensure that they fit project needs and that they will be usable for quality assurance evaluations (CMMI for Services, Version 1.2, 2009).

The second risk is that of objectivity. Objectivity is the main prerequisite in order to perform quality assurance. Yet, it could be understood that people who belong to the same department can not always be objective, especially when they have to record defects, mistakes and non-compliance issues of their colleagues.

The first step proposed for implementing the PPQA process area is that the maintenance manager along with his chief mechanic and electrician could comprise a quality assurance team and design a basic checklist to control if activities containing potential risks for pasta contamination are implemented according to the corresponding technical descriptions and take corrective actions. Moreover, the new objective of defective productions measurement due to deficient or ineffective maintenance or due to equipments breakdowns that was proposed on the MA process could support the process.

The process implementation could also be aided by training maintenance personnel on quality assurance aspects. This could be done by the company’s quality assurance department or off-the-job from external training companies.

The implementation of PPQA will support the maintenance external effectiveness by aiding the company’s effort to satisfy its customers and it could be assessed on measurable criteria.

**Requirements Management Process Area**

Requirements Management (REQM) process area targets on managing requirements of the department’s projects and activities and on identifying inconsistencies between these requirements and the projects’ plans and outputs. In order to manage requirements, which is also the specific goal of that process, the requirements must be firstly understood. Then, the concerned stakeholders must commit and approve the requirements. Figure 8a illustrates the
process area according to the CMMI for services model and Figure 8b shows how that process could be implemented by the maintenance department.

The maintenance department practices a similar process, which could be described as effective, since the requirements in maintenance materials are identified on time through the scheduling of activities and there are no evidence of delays on projects and activities due to lack of materials. The effectiveness is coming both from the personnel’s experience and commitment and from the currently employed procedure.

The Maintenance Requirements Definition, as the process is defined by the maintenance department, focuses on determining the maintenance requirements both from the perspective

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**Figure 8a.** REQM Process Area  
**Figure 8b.** Maintenance REQM

(Source: CMMI for Services, Version 1.2, 2009)
of workforce and that of materials. Maintenance Capacity and Facilities Management is the process that manages workforce, tools and spare parts in order to successfully implement maintenance. Therefore, the first step is that the maintenance department should remodel these processes and manage material requirements separately than workforce requirements. The fact that there is no stock-keeper is a disadvantage because there have been cases where the spare parts could not be found, or it was believed to be on stock but they were already used. Thus, the chief technicians should be delegated to identify and report the requirements in spare parts, tools and materials based on:

- criticality for equipments’ operation,
- frequency of use and quantities used and
- scheduled maintenance activities.

The maintenance manager could prepare and provide to chief technicians a checklist for checking the requirements. The information from that paper could be transferred to the manager’s PC database in order to better control requirements, follow the trends on requirements and keep notes on requirement changes. These changes should be recorded on that PC database for future analysis. The use of a checklist and a PC database could improve the process and reduce phenomena of “lost materials” and delays on maintenance activities. The COM process, described previously, could also aid the REQM process by identifying and configuring the spare parts and tools, so that their position can easily be traced.

**Supplier Agreement Management Process Area**

The Supplier Agreement Management (SAM) process establishes a firm base between the maintenance department and its cooperators and ensures a qualitative support of the maintenance activities. Figure 9a illustrates the process as described by the model and Figure 9b illustrates how the process is followed by the maintenance department.
The SAM process area is exercised by the maintenance department and it is based on agreements regarding the quality, quantity, offered services, prices, time response, delivery and payment terms and their control. The suppliers are assessed once per year on predefined criteria.

The SAM process is not a separate process, but embodied in the Maintenance Capacity and Facilities Management process. Thus, similarly to the REQM process, the SAM process must be distinguished in order to be better controlled.

**Service Delivery process area**

There are strong arguments indicating that the maintenance department should adopt and should develop the Service Delivery (SD) process area. The fact for example that during the last years two of the most experienced technicians have been pensioned and at the same time the equipment has become even more complicated is a risky situation. Yet, the production has been increased during the last years, the availability indices of production equipment have...
been improved and the overtime employment of technicians has been dramatically reduced. The above results came because the maintenance department placed great importance on selecting new technicians, on training and development of its personnel and studied in detail the maintenance needs of the plant and the most effective ways of addressing them. This indicates a tendency to support and ensure service delivery and continuity.

Moreover, the use of a software database could be very helpful for the planning and control of maintenance activities. It will help the maintenance manager to get rid of excessive paperwork and it will inform him for forthcoming maintenance needs based on the scheduled and actual data saved on it.

Figure 10a illustrates the process area as described by the model and Figure 10b illustrates how the process should be followed by the maintenance department, with improvements included.

**Figure 10a.** SD Process Area  
(Source: CMMI for Services, Version 1.2, 2009)
5 Conclusions and recommendations

5.1 Research conclusions on applying CMMI-SVC, V1.2 on maintenance

The studied maintenance department could adopt the CMMI-SVC, V1.2 model and potentially achieve a maturity level 2 by implementing the process areas required by the model for the specific maturity level. Table 5 summarizes these process areas and shows their current status. The process areas that a minimum 60% of their specific practices are implemented by maintenance are regarded as “Adopted”, while the rest of them are regarded as “Not Adopted”. The 60% limit is regarded as adequate by the authors, since it set a specific quantitative threshold and helps maintenance processes to achieve their goals in practice. New actions are proposed for improving the implementation of adopted processes and for initiating those missing. Reference is made to the relative advantages and risks of implementing these new actions and to possible ways of measuring their effectiveness.

Table 4. Requirements and recommendations for the maintenance department in order to accomplish the target of maturity level 2.

<table>
<thead>
<tr>
<th>Process Area</th>
<th>Maturity level</th>
<th>Status</th>
<th>Additional actions for improvement</th>
<th>Measurement</th>
<th>Advantages of additional actions</th>
<th>Risks of additional actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>COM</td>
<td>2</td>
<td>Not Adopted</td>
<td>Application of a complete, computer-aided configuration system.</td>
<td>Audit the maintenance COM records</td>
<td>Facilitates maintenance delivery and continuity</td>
<td>Lack of commitment jeopardizes the effort</td>
</tr>
<tr>
<td>MA</td>
<td>2</td>
<td>Adopted</td>
<td>Adherence on proper data collection. Defective production measurement due to maintenance. Questionnaires answered by production.</td>
<td>Audit the maintenance personnel’s logbooks. Quality measurable goals</td>
<td>Supports maintenance management information needs</td>
<td>Lack of control from the manager attenuates the data collection</td>
</tr>
<tr>
<td>PP</td>
<td>2</td>
<td>Adopted</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>PMC</td>
<td>2</td>
<td>Adopted</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>PPQA</td>
<td>2</td>
<td>Not Adopted</td>
<td>Objectively evaluate processes and activities together with chief technicians by using a quality checklist.</td>
<td>Checklists. Record of defects due to maintenance</td>
<td>Improve the maintenance processes. Increase external effectiveness</td>
<td>Objectivity is crucial, but difficult. Selection of personnel</td>
</tr>
<tr>
<td>REQM</td>
<td>2</td>
<td>Adopted</td>
<td>Assignment of responsibilities to personnel. Use of spare parts checklist. Application of computer-aided software system.</td>
<td>Lost hours of maintenance services due to non correct REQM</td>
<td>Reduction of production lost hours. No need for a stock keeper. Money savings.</td>
<td>Lack of commitment from the maintenance personnel.</td>
</tr>
<tr>
<td>SAM</td>
<td>2</td>
<td>Adopted</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>SD</td>
<td>2</td>
<td>Adopted</td>
<td>Computer-aided service request system. Extensive training and development of personnel.</td>
<td>Service satisfaction questionnaires to concerned departments</td>
<td>Improve response to services</td>
<td>-</td>
</tr>
</tbody>
</table>
COM is a process that needs to be reviewed by the maintenance manager. Positive is regarded the fact that what needs to be identified and configured is known and thus effort is required for the implementation of the described specific practices. The use of a software database could facilitate the search for information and the maintenance delivery. The implementation of COM will support maintenance continuity since the information will be available to everyone. The role of the maintenance manager is crucial because any lack of commitment from his part could jeopardize the effort.

MA could be enhanced with two measurable goals referring to the defective productions due to maintenance and to the quality of services offered to the plant. The first could be easily practiced since the Quality Assurance and Production departments keep relative records, while the second could be accomplished by providing a service-satisfaction questionnaire to the concerned departments to fill it in. The proposed actions will provide valuable information to maintenance manager in order to improve the quality of services offered. Moreover, the maintenance manager should insist on collecting the technicians’ log-books so as to avoid attenuation of their briefing, which is crucial for the overall implementation of the MA process.

PPQA is a non adopted process area. The preparation and evaluation of a checklist with potential hazardous for the final product maintenance activities could improve maintenance processes and its offered quality services. Selecting the personnel to evaluate the processes is crucial because they must assess activities and processes objectively.

REQM, which is an adopted process area, needs to be firstly distinct. The use of a software database in accordance with a checklist could reduce phenomena of lost maintenance and production hours, due to lack of maintenance materials. The last could also be used as a measurable criterion for the performance of the process. Implementing the REQM process could also save financial resources. The role of personnel delegated to follow the requirement needs is crucial otherwise the effort will attenuate.

Finally, the SD process area could be improved by the use of a software database, which could help the retrieval of maintenance requests on time and without the use of excessive documentation. The training of the technicians is also important in order to improve the maintenance services delivered to the company.

5.2 Recommendations for the application of CMMI-SVC, V1.2

The IT sector offers software tools that could be used to improve maintenance. Maintenance strategy could be integrated into ERP, as the model proposed by Nikolopoulos et al. (2003),
or a software database could be used, evolved in-house by the maintenance department and
the company’s IT department. The last is proposed by the author because it could be tailored
to the exact needs of the maintenance department and it could be gradually evolved. The
software database could support maintenance on gaps identified on maintenance scheduling
information, spare parts requirements management, and configuration management.

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