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Maintenance management in the Egyptian water sector: will management provide an answer to maintenance?

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Maintenance has become a major challenge for the Egyptian water sector. The Fayoum Drinking Water and Sanitation Company seeks to address this by the application of comprehensive maintenance management to the entire scope of its operations, both drinking water and sanitation. Maintenance management focuses on managing the maintenance process and all the different contributing factors that at the end of the day determine the difference between effective management or not. These concepts have been tested in the framework of the Fayoum Drinking Water and Sanitation Project for application in Urban Water Supply and Sanitation. The lessons learned are documented in Guidelines for Maintenance that provide clear guidance in 5 critical areas, i.e. asset information, maintenance processes, organisation, resources, and management. A summary of the model is presented and the lessons learned are presented and its impact on the current articulation of the Fayoum Maintenance Model highlighted

The forgotten art of maintenance

The story behind this paper starts in the year 1981 when one of the authors had the privilege to participate in the introduction of maintenance management in the province of West Java, Indonesia, in a joint effort with the University of Technology of Eindhoven and the Water Utility of Friesland, both from the Netherlands. It was in that environment an unusual combination of a clear conceptual framework with a very pragmatic approach and it was received enthusiastically. Twenty years later, the same author found himself in Fayoum, Egypt, working with another water utility when the question of maintenance management arose. The general consensus at the time was that Egypt is not ready for maintenance and the Egyptian technician has no affinity for maintenance. The subject was closed, but only to come up when the current, fifth, phase of the Fayoum Drinking Water and Sanitation Project was started up and the Utility found itself faced with the task to operate and maintain a large number of new wastewater treatment plants (WWTPs) and collection systems. Inadequate maintenance was identified as the source of most operational problems but still no adequate maintenance management system was articulated. Good maintenance was found at some of the venerable Egyptian utilities but it seemed more a question of strong maintenance managers and tradition than a system. Searches on Internet and consultation among colleagues yielded the same negative result.

And the challenges for the Fayoum Drinking Water and Sanitation Company (FADWASC) were daunting indeed: it served the Governorate of Fayoum, located some 100 km SE from the capital of Cairo, with a service area of 1,800 km^2 and a population of approximately 2.7 million. Its wastewater operations virtually exploded in a period of 4 years with the commission of 7 major WWTPs with an accumulated capacity of 78,400 m^3/day (an increase of 79%) and 41 wastewater collection systems with 83,000 additional house connections (an increase of 72%). It marked a movement from large systems to smaller systems in a rural setting. The organisation was dominated by water supply and not ready at all to cope with this new field. A new organisation for wastewater had to be re-engineered overnight but wastewater tariffs did not and do not cover the operating costs, resulting in the inability of the Utility to offer attractive salaries and the tendency to "slash" operating costs, most dealing with maintenance and logistics. The main challenge, however, is human resources. More than a decade of a "Personnel Stop" inspired by the IMF, has resulted in a virtual absence of engineers in the age group of 30 – 50 years: senior engineers are retired (at the age of 60) without qualified successors. The Utility is unable to attract young qualified engineers and finds itself losing engineers constantly to the attractions of the Gulf.

A conceptual model of maintenance management

Maintenance management

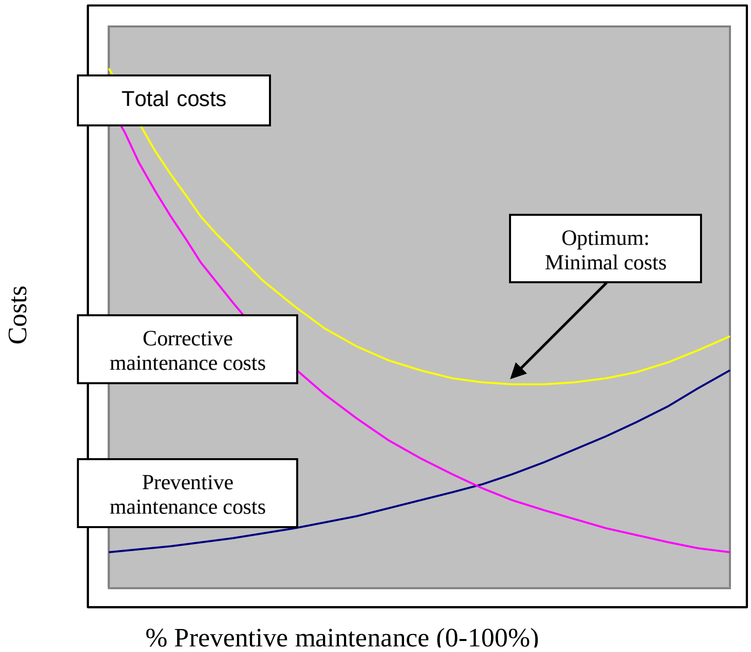
The authors found most managers in FADWASC typically ill at ease with maintenance with the tendency to lose themselves in technical details that are counterproductive. Managerial issues and learning from past experience are as a rule neglected. We submit that maintenance is a management process in which the quality of maintenance is improved in a continuous learning cycle. The two fundamental processes of maintenance management are **preventive** and **corrective maintenance.**

i) *Preventive maintenance* aims at keeping the equipment in good operational condition and the prevention of failures. It can be scheduled in advance in order to minimise disturbance to operations. In most cases, preventive maintenance is relatively straightforward and can be handled by staff of the Utility.

ii) *Corrective maintenance* is reactive and aims at solving failures. It comes at unexpected moments, disturbs operations, is more complicated and expensive, and it frequently requires technical skills that are not available in the utility. Statistics in our pilots show that failures are either repaired within a couple of days or after 6 months. Delays are usually caused by factors outside the scope of line management such as logistics, procurement, and outsourcing, and represent in fact a corporate failure.

Failures are a fact of life and cannot be avoided. It is, however, by managing its maintenance process that a utility is able to reduce the incidence of failures and ensure that repairs are carried out with minimal delays against acceptable costs. In other words, it aims to reduce the incidence of failure by adequate preventive maintenance and thus reducing maintenance costs as shown in Figure 1.

Figure 1: The Balance between Preventive and Corrective Maintenance



The art of maintenance management is finding an optimal mix between preventive and corrective maintenance, and ensuring that the necessary maintenance is carried out in an efficient and effective manner. The aim is to minimise the incidence of failures against acceptable costs and to ensure the availability of the equipment for the purpose it was installed for. The targets for maintenance management can be expressed in terms of efficiency and effectiveness, as shown in Table 1.

Table 1. Targets of Maintenance Management			
Targets	**Objective**	**Key Performance Indicator (KPI)**	**Definition**
Effectiveness	Functionability	Functionability index	% of equipment in working condition over a defined period of time
	Reliability	Number of failures	Number of failure reports over a defined period of time
Efficiency	Economic efficiency	Maintenance unit price	All (preventive and corrective) maintenance costs per unit
	Responsiveness	Response time	Time to rectify a failure after it has been reported

The Maintenance Model

These principles subsequently have been applied in a number of applications dealing with wastewater treatment, wastewater collection, and drinking water distribution with a modest start into drinking water production. The applications have been tested, improved, and fine-tuned in the different operations of an ordinary Egyptian Utility during a period of at least 2 years. These systems have past the first tests of time and have been documented in operational guidelines that define the 5 critical areas that constitute the Fayoum Maintenance Model, viz. (i) asset information, (ii) maintenance processes, (iii) organisation, (iv) resources, and (v) management. The 'Guidelines for Maintenance' constitute a formal policy document of the Utility containing a comprehensive definition of terms and concepts as well as concrete instructions for its application to all parties concerned.

Asset information

Management is based on reliable information, tailored to the needs of the decision maker. For our purposes all data is processed and stored in databases, whether or not in combination with a Geographic Information System (GIS). These maintenance databases are stand-alone systems, dealing with treatment plants or district maintenance centres responsible for all networks in its district. The starting point has been that all activities need to be documented in order to (i) know the maintenance history of each asset, and (ii) be able to evaluate the effectiveness of operations.

Maintenance starts with information about all "productive" assets, including civil works, of the installations operated by the utility. This means that at least information about technical specifications, maintenance procedures with required spare parts and materials, crafts, etc, and the corresponding safety procedures needs to be collated. Asset information for electro-mechanical equipment, broken down per manufacturer and model, is managed at the corporate level (equipment register), also inspired by the necessity to update these data periodically. Maintenance procedures tend to be generic, focused on the type of equipment, e.g. submersible pumps, but become more and more specific as failures are systematically analysed. Other complex applications such as GIS (distribution and sewer networks) are also operated at the corporate level for reasons of economy and available skills. Information is regularly imported from these systems into the maintenance databases.

It has become common practice to manage maintenance through a Computerised Maintenance Management Systems (CMMS). These sophisticated applications have been developed for complex industrial installations and can handle all related issues, such as planning of maintenance, documentation of equipment and related maintenance needs, itemised descriptions of maintenance activities including standard safety precautions, scheduling and tracking of preventive and corrective maintenance Work Orders, organisation and monitoring of materials and spare parts inventory, management and follow-up of procurement of parts, allocation of work to staff, cost control, reporting and analysis. The main CMMS software packages available on the market basically perform the same functions. The limited insight into the structure of a CMMS, however, drives Maintenance Engineers to rely more on the system than on common sense. We submit than an "open" database will stimulate a much better understanding of the basic maintenance processes of the Maintenance Engineers and will subsequently in at the end of the day produce better maintenance management decisions. The "open" database approach is especially suited for a first acquaintance with maintenance management in an environment where engineers with IT-expertise are lacking. These simple databases in Access have been developed and maintained in close collaboration with the IT Department of the Utility, ensuring both ownership and sustainability.

Maintenance processes

The control of the maintenance processes constitutes the heart of any Maintenance Management System. Two maintenance processes, basically document cycles with all the necessary steps and documents, i.e. Failure Reports and Work Orders, have been defined. Preventive Maintenance is triggered by the Maintenance Procedures in the Database and scheduled on a weekly basis. The Work Order (WO) contains in that case a.o. a checklist for the scheduled maintenance tasks and required spare parts. Corrective Maintenance is triggered by a Failure Report and depending on the urgency tackled immediately or entered in the weekly planning cycle. The Maintenance Engineer produces (and closes) WOs in the Maintenance Database but the WOs themselves are distributed on a daily basis by the Chief Technician, supervised, and signed off by him. A WO is subsequently closed in the Maintenance Database but only if the maintenance job is really finished. Quality Assurance is applied by a combination of monitoring the “paper trail” of maintenance jobs and condition appraisal of maintained equipment.

The Maintenance Engineer and ultimately the Line Manager will monitor the outstanding WOs and undertake all necessary actions to bring the WO to a successful completion. The danger of counterproductive bureaucracy is very real and steps needs to be taken to minimize the number of WOs by regrouping maintenance jobs into one job. Daily and weekly preventive maintenance are covered by standing instructions and do not require a WO. Urgent failures are tackled immediately and the corresponding WO is captured at a later stage.

Organisation

Maintenance Management is a new element that needs to be reconciled with the existing Organisation. It should, however, not lead to the misguided desire to create a special Maintenance Organisation that stands in isolation from the existing O&M organisation. It is necessary to create drivers at corporate level who will coordinate, integrate, and direct maintenance at lower levels. Expert knowhow for failure analysis, quality assurance, and the upkeep of the Equipment Register is required. The Utility should also address the organisational constraints that occasionally prevent the full use of scarce (maintenance expertise).

Operational maintenance takes place in the triad of the Line Manager who bears the ultimate responsibility, the Maintenance Engineer charged with planning, work preparation, documentation, reporting, and analysis, and the Chief Technician who drives the Maintenance Technicians and ensures that work is carried out according to standards.

The number of maintenance staff is normally limited and can be easily integrated within the existing O&M organisation. Exception should be made for repetitive maintenance work that requires frequent displacements (e.g. distribution network, lift stations in the sewer networks, etc.) that are better off with dedicated Maintenance Teams. The Guidelines define the organisation of maintenance with revised organisation charts for each Unit, stipulating the maintenance tasks and responsibilities of the key positions, and indicate the linkages to other Units, i.e. Central Workshop, Stores and Procurement, and Technical Support.

Resources

Scheduling maintenance means the allocation of resources to a maintenance job. We have for the time being distinguished between (i) Human Resources, (ii) Spare Parts and Materials, and (iii) External Capacity.

Human resources

The skilled technician constitutes the foundation of any successful maintenance organisation. Maintenance jobs should only be assigned to technicians qualified for the job at hand, hence the definition of crafts in the maintenance procedures. Skills for common maintenance tasks of electro-mechanical equipment, i.e. preventive maintenance and the most common repairs, have been subsequently inventoried, classified, and matched with the available skills. Not surprisingly, available skills were sufficient to cope with preventive maintenance tasks but clearly insufficient for repairs. Eight training courses for basic maintenance skills have been subsequently developed. It should lead in the long term to a system of certification for Maintenance Technicians. For the time being, the successful completion of introductory training is a condition for the extension of labour contracts.

Spare parts and materials

Heavy bureaucracy, lack of knowhow about spare parts but most of all lack of communication between Line Departments and Stores impair the availability of spare parts and materials. The introduction of Maintenance Management has been instrumental to re-establish communications and to introduce the Minimum Stock concept. Regular tenders for spare parts (obligatory under current regulations) with the occasional direct order maintain minimum stock levels. Lack of know-how on spare parts (not helped by the fact that most storekeepers only read Arabic) is a constraint for the identification of spare parts (a recurring problem during the handing over of new installations) and hence the issue and re-order of these components. The answer is the establishment of specialised central stores for electro-mechanical equipment, training, and assigning storekeepers with an adequate technical background.

External capacity

Maintenance jobs that cannot be handled by the maintenance technicians on site, are conventionally contracted to workshops and/or specialised contractors (outsourcing), resulting in delays, inadequate workmanship, and a general lack of transparency. The alternative of insourcing, i.e. the creation of specialised units with the necessary resources to cater for all the needs in the organisation, has been ignored with a few exceptions. Insourcing will make a better use of the scarce resources, most notably of skilled technicians, improve the quality of the work done, and enhance transparency. With a few notable exceptions, the Utility should be able to undertake all maintenance activities on its own. Examples of insourcing are a.o. a Central Workshop (charged with a.o. Quality Assurance of outsourced work), permanent maintenance teams, and a Central Store.

Management procedures

Management is the most critical area to ensure that Maintenance Management delivers and its sustainability. 4 important activities have been defined in this context dealing with (i) Management Reporting, (ii) Failure Analysis, (iii) Key Performance Indicators, and (iv) the Annual Planning Cycle.

Management reporting

Maintenance is as good as the Management of the utility allows it to be. It requires that Management is systematically and sufficiently informed on a needs-to-know basis, is aware whether targets are met, and initiates the necessary corrective actions. Regular Management Reports tailored to the needs of the concerned Manager, provide that basis. The Maintenance Databases provide templates for these Management Reports.

Failure analysis

Maintenance will gradually improve by learning from the problems encountered. Failures are (i) in the databases characterised by failure modes, i.e. the way the failure occurs and its impact on equipment operation, (ii) statistically reviewed, and (iii) eventually analysed. Critical failures that will impact on the process, e.g. cabling in WWTPs, are thus identified and the appropriate responses formulated, e.g. revised (preventive) maintenance procedures, modifications, etc.

Key Performance Indicators

It is important to stress at all time that targets must be met. It will provide the Maintenance Team with guidance to the desired outputs, it will stimulate competition among peers, and it will inform Management in one glance on the performance of the concerned units. Key Performance Indicators (KPIs) are defined per sector. Annual values (the targets) are negotiated between the Line Manager and Management as part of the annual planning cycle. Typical targets are a.o. for Distribution 15% Leakage and for WWTPs a response time of 1 month for failures. The KPIs are reported monthly and provide the basis for "Performance-Based" Incentives for the units. Similar incentive systems have been applied successfully in water production since 2002 and link the amounts of incentives paid to the degree the targets are met.

Annual Planning Cycle

The Annual Planning Cycle coincides with the budgeting process and provides a sound basis for the budgets, ensuring also that the necessary budgets are made available on time. The Cycle comprises a component dealing an appraisal of the existing infrastructure and available resources and an Annual Maintenance Plan with the necessary resources, duly translated in a budget.

A Condition Appraisal of all the assets operated by the Utility, based on the maintenance statistics, kicks off the Planning Cycle and should arrive at proposals to overcome backlog in maintenance, to modify underperforming equipment, and/or to replace obsolete equipment. This should in due time lead to Capital Investment Planning.

The basis for the Annual Maintenance Plan is provided by the demand for preventive maintenance and projections of expected failures, fine tuned for revised targets and/or maintenance standards, and scheduled operations. The Plan constitutes a detailed planning of all maintenance activities for the coming (fiscal) year, both scheduled preventive maintenance and anticipated corrective maintenance. It shall elaborate spare parts and materials, equipment and tools, and human resources (new positions and training needs).

Rollout of the Fayoum Maintenance Model

The strategy for the introduction of Maintenance Management comprised three stages: an initial Feasibility Study, followed by a Pilot in which the entire concept was applied and tested, and finally a company-wide sector-wise Rollout.

Initial activities started in 2007 with a Feasibility Study into maintenance management for Wastewater Treatment Plants. In a second phase during 2008 pilots have been launched for a WWTP, Lifting Stations (upstream of the WWTP), a District Maintenance Centre for collection system networks, and a second District Maintenance Centre for Distribution. The Fayoum Maintenance Model was developed during this phase and a standard implementation scenario designed. Precise and verifiable criteria have been formulated to monitor progress of the different “projects” were scored accordingly. The third phase of Rollout started started in 2010 and shall be achieved by mid 2011.

Wastewater treatment plants

Maintenance Management is currently applied in 6 WWTPs and 2 more coming up. In the meanwhile Fayoum was requested to share its experience with 5 other Egyptian Utilities. For this Rollout, the project has collaborated with the USAID-funded Water and Wastewater Sector Project in the development of MASTER, a basic fully Arabised CMMS that is likely to become the standard in the Egyptian Sector.

Wastewater collection

A spin-off has been the initiative of a young Maintenance Engineer to develop a manual system for Maintenance Management to the Lifting Stations of the City of Fayoum (>15 units) by the creation of a special Maintenance Team that would tackle the more complicated preventive maintenance. This system gave satisfaction and has evolved in permanent Maintenance Teams covering the entire Governorate, using the Maintenance Database developed for WWTPs. Maintenance of collection systems comes down to cleaning (preventive) and the removal of blockages (corrective) by the operators in place, with the support of a District maintenance engineer. Analysis of blockages have led to the identification of “black spots”, place that are frequently blocked by waste thrown in the system (markets, butchers, etc.) or technical problems. The target given to new systems is to eliminate all “black spots” within 6 months.

Water distribution

Work on distribution was triggered by the conclusion that the current estimated levels of Non-Revenue Water (34%) made leakage reduction top priority. Maintenance management is seen as the “institutional” guarantee that leak reduction is taken up of a routine task of the Maintenance Districts. The procedures for corrective maintenance were streamlined, linked to a “hotline” for consumer complaints, and a special preventive maintenance team has been created per district with its own means of transportation, a GPS, and a complete set of network maps. A special case is made for the backlog in maintenance that in some cases address situations that have existed for years. Ample use has been made of an existing Asset Management System/GIS that provides the precise locations and technical specifications of the distribution assets. Data from this system is imported but vice-versa important feedback on the accuracy of available data has started to come in.

Drinking water treatment plants

Work in Drinking Water Treatment Plants has been postponed until the system has been fully tested in WWTPs. A first pilot is underway for the New El Azab Treatment Plant (5,200 l/s) and we trust the system will go “live” by mid 2011.

Issues

A number of issues have emerged during this development process that are useful to investigate in detail.

Human resources

The main constraint during the rollout has been the lack of human resources, initially the lack of Maintenance Engineers but soon overshadowed by the lack of skilled technicians. It is a fatal combination of a lack of (i) availability, (ii) skills, and (iii) motivation. Availability is not only a question of (i) recruiting and retaining personnel but also of (ii) using available expertise. Human Resources Management falls outside of the scope of Maintenance Management but the Fayoum Maintenance Model contains provisions to improve the attractiveness of the Utility as employer by the targeted use of incentives and allowances. Insourcing moreover is a powerful tool to use scarce expertise that is hardly used up to now. The concept of craft has helped to focus training on the specific skills required and will lead to a certification programme that will motivate technicians to raise and maintain their skills. Motivation in our experience is a combination of appreciation and remuneration. We aim to create a maintenance community where professionals exchange experiences and help each other out. Regular progress meetings per sector will provide a forum for these exchanges. A Junior Management Development Programme comprising job rotation, training, guidance and exposure, will reinforce this process.

Spare parts

Frequent lack of spare parts leads to delays in repairs and higher costs. Unavailable spare parts are the symptom of failed logistics at all levels. The Utility made a good start to adopt the Minimum Stock concept but this will not deliver on its promises if stores management is not brought up to level. This requires as a minimum professional storekeepers with a sufficient technical background, a good interface between the technical and accounting departments, and active procurement. We have opted for the creation of a Central Store with a professional management that will drive the strict application of the minimum stock.

Savings in maintenance costs

A frequent cited justification for maintenance management is savings. It is easier said than demonstrated in an environment where maintenance is neglected and losses in “productivity” not considered. Maintenance costs will certainly initially increase during the implementation phase compared to a situation where maintenance was limited to repairing serious failures. Elimination of backlog does not always to be very costly. During the implementation of the system in 3 identical WWTPs, 32 cases of outstanding failures, some older than 18 months, have been identified, some of them seriously impacting on the overall performance of the plant. Within 4 months 21 of these failures have been overcome with a total cost of 9,300 £E (1,500 USD). On the other hand, we have also undertaken major rehabilitation contracts to overcome years of neglect, the price of maintenance not carried out. The Minimum Stock should result in savings through better procurement as will the reduction of outsourcing.

Need to change the culture

Experience during implementation revealed good progress in the application of the maintenance processes, in overcoming the backlog in the maintenance, and in solving the lack of spare parts. Managerial aspects on the contrary pose difficulties and this is very much related to the interaction between Line Management and Senior Management. There is a general misunderstanding at all levels about accountability, i.e. the need to report, what to report, and how to act on reports. This should be addressed by the creation of different platforms to monitor systematically performance and linking performance to incentives. Direct monetary interest is an additional incentive for a more active management. A frequently encountered constraint is the genuine conviction of some senior staff that the Utility is not ready for maintenance and every small setback confirms them that they are right, a self-fulfilling prophecy. It shall be necessary to take these engineers through an accelerated development for the managerial handwork and to create a countervailing force within the Utility. Frequent progress meetings designed to start a process of communication between professionals, have provided a sound platform.

Conclusions

We conclude that the Fayoum Maintenance Model is viable, that its applications work and are understood by the users. It has streamlined working procedures, rendering them more transparent. The conventional approach to focus on corrective action is expensive, difficult, and disruptive. An optimal mix of preventive and corrective maintenance shall lead to a more economic exploitation, can be handled by Utility staff, and will avoid disruptions in operations.

We have opted for an implementation strategy that focused on the managerial aspects and learning while doing. This seemed the only possible approach in a rapidly evolving organisation that was almost created overnight. This has worked in general but we have come across hard conditions that must be respected at the same time:

i) *Skilled maintenance technicians are essential* and usually some experience technicians that meet the requirement are available: ensure that full use of the (limited) in-house expertise is possible by the necessary organisational and logistical provisions (insourcing);

ii) *Restitution of the neglected standard administrative procedures*: a good example here are the existing procedures for stores management and procurement. It is a matter of better communication, coordination, and follow-up between the different hierarchical levels and/or sectors (technical and administrative). It is a learning process for all parties that has to be institutionalised during the implementation;

iii) *Drivers*: The implementation strategy needs to be driven by a senior manager who understands maintenance and is able to “maintain” the system

iv) **Early successes will pave the way to higher morale and a positive attitude**. The elimination of the backlog in maintenance and the application of the minimum stock concept are easy to implement. Solving the backlog in maintenance quite often results in major improvements against minimal expenditures (low cost/no cost). It installed a sense of professional pride and self-confidence in maintenance staff.

We have been very fortunate that we have been given the opportunity and the means to develop and test the concept of Maintenance Management for Urban Water Supply and Sanitation Infrastructure. It has been a process of trial-and-error, a fight against our own prejudices and credulity but it produced at the end a viable product that is tailored to the needs and the capacities of its users with the potential for further development and sophistication.

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