COST ASPECTS OF PLANT AUTOMATION – COST OF OWNERSHIP

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Abstract: At a first glance low cost automation could be regarded as cheap hardware (sensors, actuators and controller). That is of course an important point to consider. But today we are looking for a cost effective life cycle of an automation system: design, production, operation, maintenance, refitting or recycling, and also human skill are important factors to consider. Despite relative expensive components the complete automation system can be cost effective with respect to operation and maintenance. The contribution exemplifies these considerations on automation systems in plants.

Keywords: life cycle cost, e-service, e-maintenance, human-machine collaboration

1. INTRODUCTION

Reducing the Life Cycle Costs or Cost of Ownership of automation systems in plants becomes an important task within the subject of Low Cost Automation or better cost effective automation. The whole chain of design, production, implementation, operating, maintenance and reconfiguration or recycling comes into consideration. For instance, some components of a system can be expensive if the reconfiguration- or maintenance-costs will be reduced.

Control technologies experienced a significant development driven by the progress in innovative sensors and actuators, and the performance of computer systems, including embedded systems for control. Recent developments of communication technologies have led to novel distributed control technologies including systems with wire and wireless communications in the control loops and networked systems with multiple interconnected objects. These developments should be used to reduce the cost of plant automation (Ollero et al, 2002).

Cost of ownership analysis makes life cycle costs transparent, regarding purchase of equipment, implementation, operation costs, energy consumption, maintenance and reconfiguration. It can be used to support acquisition and planning decisions for a wide range of assets that bring significant maintenance or operating costs across a usable life. Cost of ownership is used to support decisions involving computing systems, vehicles, laboratory and test equipment, manufacturing equipment, etc. It brings out the "hidden" or non-obvious ownership costs that

might otherwise be overlooked in making purchase decisions or planning budgets. The analysis is not a complete cost benefit analysis, however. It pays no attention to benefits other than cost savings when different scenarios are compared. When this approach is used in decision support, it is assumed that the benefits from all alternatives are more or less equal, and that choices differ only on the cost side.
In our highly industrialized countries the type and amount of automation mostly depends on the cost of labor. But automation in general is not always effective (Erbe, 1996). A recent study carried out by the Fraunhofer Institute of Innovation and System - Technology regarding the grade of automation within the German industry, (G.Lay, 2002), found out that companies are refraining from implementing highly automated systems. The costs of maintenance and reconfiguration are considered as too high. It would be more cost effective to involve well qualified operators. The same considerations were given by A. Blasi (2002): automation is not useful by itself: there are a lot of additional requirements to accomplish its function as needed, not only putting automation into the factories, putting automation just where it is needed and economically justified.

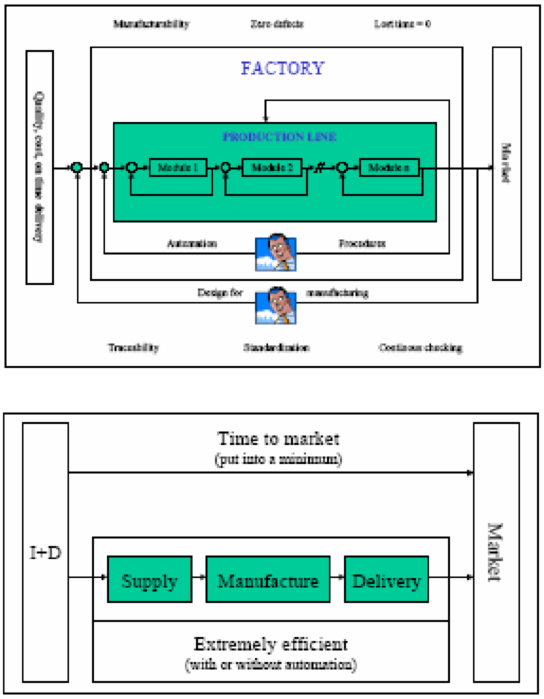

Fig. 1. Challenges of manufacturing processes with and without automation. © Blasi (2002)

Blasi considers the challenges of manufacturing processes of consumer goods. He stresses that automation helps in providing homogeneous operation, but in many operations humans can sometimes make the work better than automation systems. However, humans are failure prone, emotion depended, not constantly strainable with the same level. That has to be considered.
Figure 1 show what automation could improve if properly used.
Morel (2002) stresses the consideration of the performance of the plant, rather than the control performance only, that is interesting the owner respecting the cost; i.e. a compromise between cost of maintenance and cost of failure of the automation systems in a plant regarding the commitments to the customers or market has to be maintained (Figure 2).

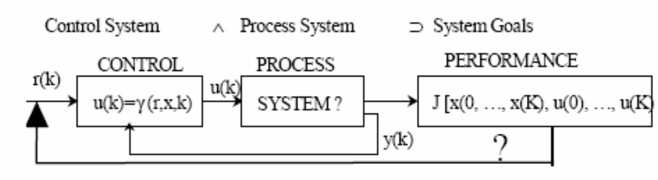

Fig. 2. A closed-loop with system performance optimization rather than control performance optimization only (Morel et al (2002)

As Blasi (2002) put it: for a manufacturing engineer dealing with plant automation it is critical to have in mind that proper automation is much more than a matter of machines and equipment. The organization of work in the whole plant involving the human experiences at all stages, and always considering possible improvements with automation or not is the challenge for engineers and management to save costs.

2. SERVICE FOR COST REDUCING

The manufactures of automation systems (components, controls, information technology) should (and do meanwhile) provide service to regularly check the state of the equipment (Hohwieler & Berger, 2002). The manufacturer carries out a data evaluation in order to deduce the availability of the equipment. This evaluation is passed on to the user. Thus the plant management receives an immediate statement about the expected availability of the equipment.
The plant management transfers information to the manufacturer, which will be further evaluated. The necessary maintenance work is then determined and entered as a suggestion to the To-Do-List of the equipments Online-Service-Logbook. The plant management can call up this information at any time in order to receive input for the planning of maintenance work. After completion, the maintenance work

is then reported to the online maintenance assistant. Thus the basis for consistent life-long documentation of the equipment is established. It is a win-win situation for all those participating in the previously described scenario. The plant management takes part in the equipment builder know-how of the system. The equipment builder is also capable of collecting data about the actual usage profile of the equipment. In this way, it is possible to adjust the offer to better match the needs for cost saving.

Within the previous scenario, the transfer of equipment data plays an essential role. During this process, security precautions must be taken in order to prevent any unauthorized access to such information. More important, all secrets have to remain within the enterprise. At the end of a service session, the enterprise receives a report of the session. The account for the services rendered is then calculated according to any given variety of pay scales. All of these steps require qualities like availability, dependability, information protection and confidentiality. Another development focuses on a systematic fault clearance, that makes run again the core

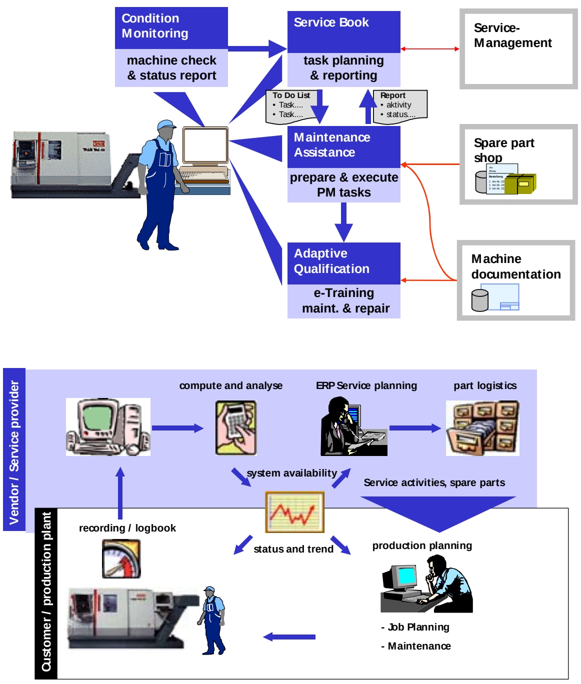

Fig.3. Combined web-service for Maintenance Support (Hohwieler and Berger, 2002)

value-adding processes of a plant. The software serves the equipment of a plant through all its lifetime: system development and construction, ramp-up, operation and to some degree at system change. The throughout collected data allow many value-added services like a systematic fault clearance, reduction of faults or by an immediately back-flow of know-how an improvement of machinery (refinement).

The complete historical data allow numerous applications and analysis. This finally reduces lifecycle costs and may be interpreted as a win-in-situation for both, service client and service provider (the equipment builder).

The Cost of Ownership is transparent to the plant management. The benefits of equipment lifecycle support arise with a Service Information Management. This concerns either the equipment itself or the service environment:

- constantly high service quality
- cost savings – in service and operation
- service can be done more quick or can be done at all (instead of unsuccessful return)
- fewer visits of technical staff on site
- less downtime and therefore reduced operational costs
- data history of the complete lifecycle information allowing for numerous analysis,
- both for development/construction and at system change.

3. MAINTENANCE

Among the main factors responsible for the performance of a plant is the availability of the machines and equipment. Therefore maintenance takes an important part in plant automation. To avoid downtime or at least minimize it is a goal. As we know downtime is not absolutely avoidable, but it should not occurred unexpected.

One has to consider a compromise between maintenance cost and the cost of failure respecting the demands of the plants target as mentioned in the introduction.

Despite the development of new maintenance strategies (Lee et al, 2004) and the efforts of service providers presented partly in section 2 one should not underestimate the knowledge and experiences of the operators of automation systems, and use their expertise if even possible. Here one has also to find a compromise between the cost of service from outside or specialists from inside and the cost of qualified operators and their permanent training. To effective empower people depends on the confidence between management and shop floor. It is not easy for the management, but this problem is solvable if it is cost reducing and every body understands it.

Operators should not be forced to always ask for help of a service, if a problem occurs, but be allowed to consider (and of course quickly): the problem is solvable by ourselves or we need help.
Under the concept of total productive maintenance (TPM) a support system was developed by Marzi and John (2002). Operators use the information provided through an agent support together with their experiences what to do to regain the normal operating state of the manufacturing system. After laboratory testing

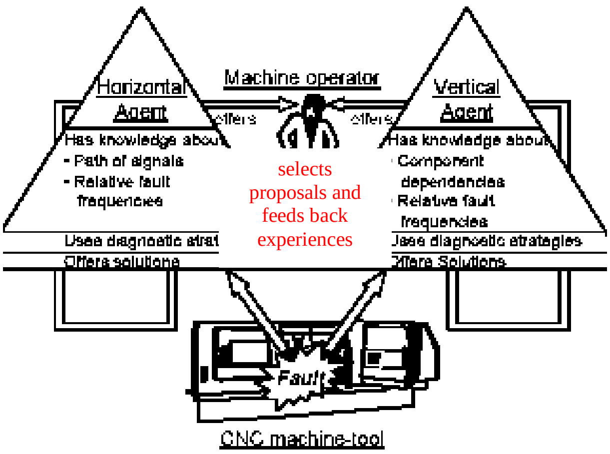

Fig. 4 a. Agent ontologies and operators interaction (following Marzi & John, 2002).

the system was enhanced and implemented at the shop floor of a small enterprise producing parts with CNC lathes. The enhancement consists of a module for extending the database for the agents with gained experience through the operators. In addition, speech output was implemented to improve the usability of the system under shop floor conditions (Figures 4a and 4b). Operating and understanding are also discussed in Erbe (2003).

Maintenance strategies and operations are considered as a complete process aiming to maintain the production resources while inter-working with other processes (energy management, quality management, etc.) to carry out the global enterprise goal. Engineering of such a maintenance system needs a holistic approach for integrating views and evaluations, not only of the systems themselves, but also for their mutual interactions and their interactions with the environment (Morel, 2002). An implementing of condition-based and predictive maintenance substitutes scheduled maintenance to decrease expenses and to improve the global performances of the automation system.

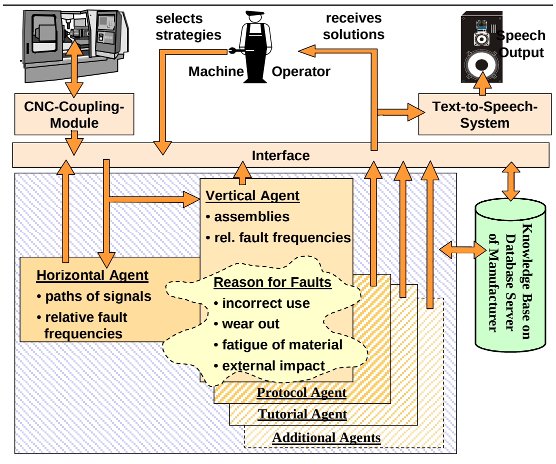

Fig. 4.b. Support system of 4a with speech output.

Studying the systems "degradation" to anticipate its failures offers an image of the future situation of the system (Lee et al, 2004). Moreover, the objective of the diagnosis process is to identify the components, which are responsible of the system degradation, in order to intervene and to restore only those components, which are degraded, or failing.
Therefore the implementation of these processes within the framework of a predictive versus pro-active maintenance strategy involves some a priori knowledge on the system and on its components with a use of this knowledge to represent the views on the future directions of the automation systems in a plant (Morel, 2002).
Maintenance should follow quickly after the first appearance of problems, and be in accordance with the actual condition of the machine. This is made possible by monitoring the condition of machine parts via signals and sensors. The status of the system is based on the condition-values, load-values and the particulars of the situation. The main idea of “Condition Monitoring Services” approach is to host and to provide electronic services for the analysis and prediction of the equipment health status using enhanced diagnostic algorithms and to deliver online assistance and additional information for related maintenance activities over the Internet (Lee et al, 2004). A set of relevant machine devices and corresponding parameters and signals that indicate present equipment status must be selected. The remaining lifetime of individual components can then be estimated. Using regular updates of the load, which are documented by the equipment, the future progression of wear is predicted. With the result of classification of equipment health status planning of maintenance and repair

activities can be improved. The main requirement is the ability of the system to record and transfer relevant signal parameters via the Internet to the remote server for data evaluation. Lee et al (2004) developed for this purpose a Watchdog Agent™ integrated in an intelligent maintenance system.

4. HUMAN INVOLVEMENT

A complete automation of assembly processes is complicate if not impossible at all. The reconfiguration of Robots doing assembly-tasks could be very costly. Humans on the other hand have capabilities that are difficult to automate, such as parts-picking from unstructured environments, identifying defective parts, fitting parts together despite minor shape variations, etc.

Physical teaming of workers and robots in a shared workspace can help to solve assembly problems and protect workers from long-term health endangering. There exist different concepts to do this.

Collaborating robots (Cobots) with operators at the shop floor are a promising development (Peshkin et al, 2001), Surdilovic et al, 2003). Virtual surfaces separate the region where the

Fig. 5. Cobot at a General Motors assembly line. © Peshkin et al (2001).

worker can freely move the payload from the region that cannot be penetrated. These surfaces or walls have the effect to the payload like a ruler guiding the pencil.

Kohler et al (2004) report on investigations with hand guided devices at assembly lines of an automobile factory. The analysis is restricted to robots assisting the workers when reducing the physical work load. But the robots power can not be controlled through the workers as cobots can. Nevertheless the investigation found that workers at assembly lines accept the assistance through robots with a suitable work organization. However, cobots could be more appropriate. It seems that some more research and development is necessary to convince managers of the economic advantage of cobots by improving assembly work when used the skills of workers assisted by intelligent devices. Figure 5 show an application of a cobot.

Regarding new maintenance strategies as mentioned in section 3 for saving costs when downtime of equipment has to be minimized, the maintenance work of human operators over

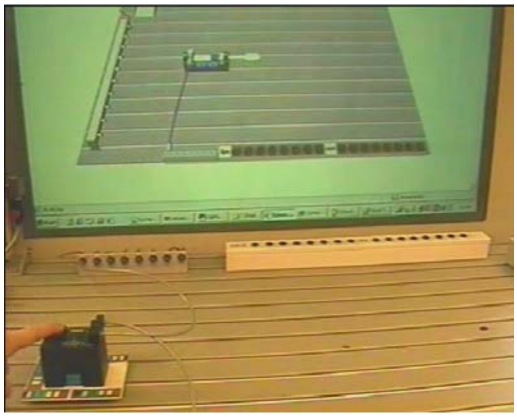

Fig.6. Pneumatic equipment: single acting cylinder and valve split into reality and virtuality.

remote sites (Human – Human collaboration) should be supported. Bi-directional tele-presence is under development. Bruns (2001) using Hyper-Bonds as a universal interface type (between reality and virtuality) goes in this direction. Hyper-Bonds refer to the theory of bond graphs. Mixed reality was first implemented for supporting e-learning, connecting virtuality to reality (Bruns and Erbe, 2003). Figures 6 and 7 show a simple application.

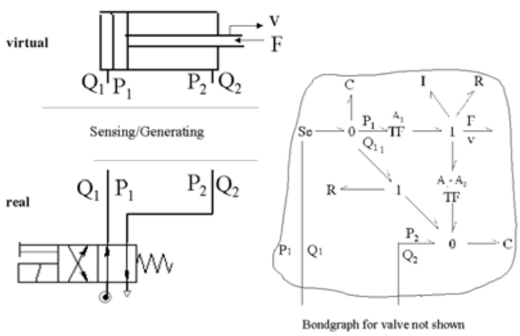

Fig. 7. Cutting of the system of by a sensing/generating mechanism (hyper-bond)

Necessary is a combination of haptic feedback with visual feedback. These developments are in their infancies. However, they bear the chance that experienced humans can get back into the control loop of plant automation with the intention to run the plant cost effectively.

5. CONCLUSION

The contribution considered recent developments for cost savings in plant automation regarding life cycle management and total cost of ownership strategies. Web based e-services are provided by equipment manufacturers. Maintenance is considered as the main cost consuming process. Recent developments of e-maintenance are promising for cost saving. Also the human-human collaboration (including a support for human – machine collaboration) has been considered.

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