MAINTENANCE MANAGEMENT IN QUICK RESPONSE SYSTEMS

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Abstract

A trend has been currently growing to integrate business logistics systems in supply chains and to implement new methods (such as Quick Response) for logistics performance increasing. All systems based on synchronization of material flows fail if production facilities in each successive production show a high number of accidents and subsequent repairs after failure. The maintenance in Quick Response systems is extremely important. The maintenance system must be clearly focused on prevention. It can be designed being based on several of modern methods of maintenance, such as TPM and RCM methods, whose principles it uses and appropriately combines. Moreover, in the maintenance management in companies involved in the chain, it seems desirable to cooperate in the maintenance with the customers and suppliers. In this paper is a proposal for modification of maintenance system in an enterprise that is part of a chain operating on the basis of the Quick Response method.

Keywords: Supply chain management, Quick response, maintenance management, Total productive maintenance, Reliability centred maintenance.

JEL Classification: M11, M21.

Introduction

A trend has been currently growing to increase efficiency of business logistics chains through their interfacing with logistics systems of suppliers and customers. Integration of business logistics systems in supply chains requires the establishment of more or less close cooperation of individual members of the chain. The supply chain collaboration is often defined as two or more enterprises working together to create a competitive advantage and higher profits that cannot be achieved by acting alone (Simatupang & Sridharan, 2005). The highest effects in terms of logistics performance improvement are achieved by applying modern methods of supply chain management, such as Quick Response (QR), Efficient Consumer Response (ECR), Vendor Managed Inventory (VM) or Collaborative Planning, Forecasting and Replenishment (CPFR). According to McMichael at al (McMichael & Mackay & Altman, 2000) QR is defined as a consumer driven business strategy of cooperative planning by supply chain partners, to ensure that the right goods, are in the right place, at the right time, using IT and flexible manufacturing to eliminate inefficiencies from the entire supply chain.

A necessary precondition for the implementation of material flow by the supply chain based on the methods described above is the reliability of production facilities constituting the production system of each company. All systems based on synchronization of material flows fail if production facilities in each successive production show a high number of accidents and subsequent repairs after failure. For this reason, the maintenance in Quick Response systems is extremely important.

Professional literature has not as yet addressed the problem of how to manage the maintenance in the Quick Response systems. In general, it deals with methods which allow increasing reliability of the production equipment, such as the TPM and RCM methods in particular. Mostly, however, these methods are described and discussed in isolation. Radical increase in maintenance efficiency can be achieved, however, just through a combination of principles of these methods. The professional literature also has not yet substantially dealt with the way the implementation of the Quick Response influences supporting business processes. For now, one can not find any theoretical view on how the maintenance system should be modified due to application of the Quick Response method. Therefore, the publication is focused on this issue.

The main goal of this paper is a proposal for modification of maintenance system in an enterprise that is part of a supply chain operating on the basis of the Quick Response method.

The proposal accent two main ideas, namely:

- This maintenance system must be clearly focused on prevention. It should be conceived on the basis of some modern methods of maintenance, such as TPM and RCM methods. But a modern, fully functional maintenance system can be designed being based on several of these methods, whose principles it uses and appropriately combines.
Moreover, in the maintenance management in companies involved in the chain, it seems desirable to establish cooperation in this area with other chain links, i.e. cooperate in the maintenance with the customers and business suppliers. Maintenance in any enterprise then takes place in the context of the maintenance management in other companies involved in the chain. This should enable inter-company linked, mainly tactical and operational management of maintenance that must be based on the principles of maintenance management of the manufacturing facility in multi-stage productions.

The main target thus identified will be achieved partly on the basis of literature research (analysis of literary data sources and the subsequent synthesis of established facts) and partly using results from primary qualitative researches undertaken from 2008 to 2010. These were conducted in Czech companies of the chemical and petrochemical industries.

**Maintenance Tasks in Quick Response Systems**

The main task of maintenance is to ensure proper and efficient operation of production equipment. Proper maintenance means removal of all accidents or breakdowns resulting in unplanned downtimes or cutbacks in production, that being at a reasonable cost. Means of achieving the desired level of reliability of production equipment (creating the production system in the company and in the chain, too) are business maintenance systems. They must, however, be adapted to the management of material flow by both the company and the chain while being able to effectively promote it.

Maintaining the production equipment must be managed in the QR systems so that:

- it guaranteed high reliability operation of the equipment with minimal repairs after failure,
- the duration of repairs was as short as possible,
- downtimes for repairs in interconnected production systems were linked to each other in a smooth and synchronized manner and caused the least possible, even short-term increases in stock,
- the maintenance management within the QR system avoided disruption of the maintenance economy. The maintenance management should be adapted in the businesses to the position that the selected manufacturing facilities became part of the material flow management based on the QR method.

To meet these requirements, it is usually necessary to modify the current method of the maintenance management in the individual companies of the chain.

**Ensuring the Reliability of the Production Facilities in the Quick Response Systems**

Each production manager must sometimes face the situation that a malfunction occurs in the manufacturing equipment, consequently resulting in the loss of production. Accidents on the production facilities usually have more consequences, such as the growth of overall maintenance costs, the emergence of extraordinary environmental costs (payment of fines), threat to the health of enterprise workers, and impairment of the company’s goodwill. It is therefore necessary to take such steps and build such a system of manufacturing equipment maintenance in enterprises that are part of the chain, so that these situations were at possible minimum, the need was as little as possible of operational, unscheduled maintenance and repair after the failure.

To reduce the number of breakdowns of production equipment, we may apply the TPM method (Total Productive Maintenance). TPM combines the practice of preventive maintenance with the concepts of total quality (Russell & Taylor, 2006). The methodology is defined by Nakajima (Nakajima, 1988) as plant improvement methodology, which enables continuous and rapid improvement of manufacturing processes through use of employee involvement, employee empowerment and closed loop measurement of results.

The objective of TPM is to maximize the efficiency of production equipment through a comprehensive prevention system, which covers the entire life of the production equipment. The substance of the method is to involve every employee, in all departments and at all levels, in the system so that they were motivated to voluntarily participate in the maintenance of the production equipment, through their involvement in small groups (Imai, 2007). One of the key elements of TPM is the autonomous maintenance. The main idea in the implementation of the autonomous maintenance is that it is the workmen themselves, i.e. operators of production equipment, who knows the facilities best in the normal operation, and they should be able to identify best the differences from the correct operation. Their ability to detect impending problems and the imminent repair after the failure may be increased through the maintenance training. Consequently, it is
possible to use their increased qualifications to better assess the current state of the equipment, but also to use it in the implementation of the simplest maintenance tasks, including routine repairs, which they can either perform themselves or they can assist in it. Their deployment is possible not only in the scheduled maintenance, but also in the repairs after failure, which will shorten their duration.

The TPM method may also be combined with other methods recommended for the improvement of maintenance services, namely the RCM methods (Reliability Centred Maintenance). Both RCM and TPM view maintenance in the broader business context and take into account the link between component failures and their impact on the business performance (Murthy & Atrens & Eccleston, 2002).

RCM can be defined as a structured, logical process for developing or optimizing the maintenance requirements of a physical resource in its operating context to realize its “inherent reliability”, where “inherent reliability” is the level of reliability which can be achieved with an effective maintenance program (Ahuja & Khamba, 2008). RCM thus serves to find the economically optimal way of maintenance of each manufacturing equipment in the long term (Moubray, 1997). Applying the RCM principles to the selected production equipment, which is part of the chain, would seem very appropriate, given the fact that the reliability of the production equipment is critical in these systems. Let us demonstrate application of the method using the example of a selected production facility.

The production equipment should be first identified as a set (in terms of maintenance) of individual parts. Subsequently, failure rate is assessed of these components and importance is examined of each failure. In the evaluation, it is possible to use the Risk Assessment Matrix.

For each defect is determined:

- the overall impact on the firm (in terms of safety, damage to property, environment and the company goodwill) and
- the probability that a failure occurs.

In the impact of the failure on the goodwill of the company, the impact should be considered on the material flow through supply chain.

The objective of this evaluation is to estimate the risk posed by each of the failures. If the size of risk is identified for each defect, appropriate activities are defined to eliminate the most serious failures (or to lessen their consequences). Simultaneously, an optimal maintenance strategy is determined for each part of the production equipment. In case of parts with the most serious risk, it is appropriate to apply a maintenance system leading to maximum reliability.

If it is desirable to provide maximum reliability for specific parts of the production equipment, the repair must be performed before the limit wear is reached. To determine the actual date of correction, it is necessary to use:

- past data on the prevalence of individual failures (and to process it through mathematical and statistical methods) and
- information about the current state, which can be identified using predictive maintenance.

A fixed term of the repair should ensure high reliability of the production equipment by exercising only the necessary amount of money for repairs. The repair is carried out only when it is strictly necessary, but before the failure of the manufacturing equipment.

By contrast, for parts of the production equipment where there is a low risk it is possible to use Corrective maintenance system. This system is acceptable especially in cases that a failure is not posing a risk of material flow interruption.

Providing a different maintenance strategy for each part of the production equipment that leads to different schedules of repairs would, however, involve extending the total repair time (and reduce the time available for production). It is therefore necessary to synchronize the performance of maintenance on the components. This synchronization is provided in merging terms of repairs to one term, or to a certain maintenance cycle. Generally, it is possible to adapt to the shortest time, or respectively to the maintenance cycle, and to plan a repair before the first limit wear is reached. But it is also possible to apply the Theory of Constrain approach and fix the date of repairs under the main part and to synchronize other recommended deadlines with it. In this case, however, it is necessary to consider the consequences of postponing the repairs, as postponing the recommended term may lead to repair costs increase as a result of the damage that would have been prevented by an earlier repair. It is therefore necessary to carry out a thorough analysis of the results of synchronization of terms to repair individual parts with the main part and then to apply measures in which it is possible. These measures are to allow extending, respectively shortening the time for repair. In an effort to extend, the basic question is: What should be done to prevent the production equipment
or its part from exceeding the limit wear? For example, the material from which the manufacturing equipment is made may be replaced with higher-quality one, or doubling of the device may be performed. Conversely, if it is desirable to make a repair before it is recommended for the part, one may ruminate contrariwise and make use a low quality material form which the spare part is manufactured (Branska & Silhava, 2010).

Accelerating Corrective Maintenance

Even the most sophisticated maintenance system, however, does not ensure complete elimination of accidents at manufacturing facilities. We must therefore prepare for them, so that subsequent repairs were carried out as quickly as possible. To shorten the downtime for repairs, we can:

- apply the 5S method
- improve the availability of personnel and spare parts.

5S method (also referred to as 5-Step Kaizen) is aimed at speeding up virtually any process. It can be used for shortening the time needed for troubleshooting. The substance of the method is restoring the order in the workplace. Everything must always be perfectly ready for action and the staff immediately knows how to proceed. 5S contains (Imai, 2007):

1. Seiri (organize, eliminate the unnecessary) in which it is necessary to separate the necessary from the unnecessary and what is unnecessary is removed.
2. Seiton (order of things) means an arrangement of things to avoid downtime caused by something that can not be found.
3. Seisou (cleaning) - lies in maintaining order in the workplace.
4. Seiketsu (personal cleanliness) - lies in the adoption of cleanliness and order as a personal habit.
5. Shisuke (discipline) - means "follow the working procedures of the workshop".

However, the thing is not just always to maintain order in the workplace and make sure that the maintenance staff masters the work practices, but if necessary the deployment of maintenance technicians must also be available. Therefore, the production facility that is part of the chain should be included in the category of "most important" or at least "important" in the differential maintenance management in each company. This should provide for the priority deployment of maintenance technicians to eliminate failure of the production facility, which is part of the chain.

However, the readiness of tools and workers provides only a partial guarantee that the repair will begin as soon as possible and will continue without any delays. The second prerequisite of the quick repair is the availability of all necessary spare parts and other auxiliary materials. This of course can be alleviated by stocks, but it is not usually possible or practical or cost effective to keep in stock everything you need to remove any trouble. For example, a unique part of the plant is used in a chemical technology production, which is to be replaced about once a year. Its purchase price is in the thousands. The replacement time is not known because the company replaces this part of the production facility only in case of its removal from the manufacturing process. The reason is cost savings in particular, because the later it must be replaced, the later a new one is purchased and the later money is spent. For this part of the production facilities, however, there is only one suitable supplier. However, he is able to deliver it just when necessary, i.e. when it must be replaced. The company addresses it by keeping this part in stock, even at the cost of increasing the carrying cost connected with inventory of spare parts. When an accident occurs, the component must be replaced quickly, but the downtime for repair is usually extended. The fact that the downtime date for repairs is not known in advance also complicates the planning. Should such a situation occur in the Quick Response systems, the impact of fluctuations in the material flow would certainly be significant. This particular problem might be solved by applying the predictive maintenance, thus improving cooperation with the supplier. If appropriate technical parameters could be found, company employees could monitor the level of wear of the aforementioned component and the correction would be better predicted. It would also be possible to share information about the development of the reference technical parameter with the supplier who could produce the necessary component and adapt its delivery to the expected start of the shutdown for repair. As a result, the time for which the component is in stock would be reduced or even eliminated and there would be savings in costs (mainly associated with storing inventory of spare parts).

In general, same principles may be applied in the inventory management of spare parts, and in particular the strategic ones, as in the replenishment of production stocks to the customers. If the company shared information with a supplier of spare parts, namely
on the planned maintenance and
on the current stock level of selected items and approaching of stocks to the order limit.

The supplier could expedite and continuously replenish required spare parts according to customer's needs. Implementation of this method of inventory management of spare parts should allow the maintenance crew to be ready for corrective repairs, while reducing the total cost of maintenance. The spare parts that are not designated as strategic can be replenished in the usual way, based on demand forecast.

The 5S Method and replenishment of spare parts based on QR methods can naturally also contribute to reducing the shutdown for maintenance also with the planned repairs.

**Interconnected Management of Maintenance in the Quick Response Systems**

When supply chain management on the basis of the Quick Response method is applied, it is necessary that the cooperation between individual members takes place not only in the management of material flows, but also in the maintenance. Its management must be conducted in mutual relations too. Improving maintenance is helped by actual information sharing among individual links on sales and demand forecasts and information on current customer requirements. If cooperation is deeper, plans of production, purchasing and sales may be shared and provided. If the customer provides the supplier with the production plan, showing the planned shutdown for repairs or directly the maintenance plan, he/she prepares him for stops of the purchases and the ability to synchronize the planned repairs. In the closest forms of cooperation based on the Quick Response method, we can apply coherent maintenance management throughout the supply chain. In this case, the same principles must be applied as for the maintenance management in the enterprise that implements the production in several production stages.

If the companies involved in the chain perform synchronized scheduling of repairs, they should apply the following principles:

- **Stops for repair should not take place in individual companies at once, because the simultaneous start-up of individual productions would mean that the businesses in the middle of the chain or at its end may experience a lack of material resources.**
- **Harmonization should take place of the standards for the repairs (repair duration, scope of repair and maintenance cycle). If not possible, the material flow can not be fully synchronized throughout the entire chain and it is necessary to cover the fluctuations in the continuity of the material flow with the stock. A simplified example of a coherent maintenance planning in this case is shown in the Table 1.**

**Table 1. Maintenance Planning in the Chain in Case of Different Standards of Repairs**

<table>
<thead>
<tr>
<th>Company (in reverse order in the chain)</th>
<th>The date of the start of the planned stop</th>
<th>The end of the scheduled stop</th>
<th>Time for stock replenishment</th>
<th>The optimal order ( q_{opt} )</th>
<th>Changes in the stocks of products</th>
<th>Daily production plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>A*</td>
<td>-</td>
<td>-</td>
<td>3 days</td>
<td>10 t</td>
<td>+ 5 t (1*5t)</td>
<td>5 t</td>
</tr>
<tr>
<td>B supplier 1</td>
<td>February 21</td>
<td>February 21</td>
<td>5 days</td>
<td>17 t</td>
<td>+ 5 t (1*5t)</td>
<td>5 t</td>
</tr>
<tr>
<td>C supplier 2</td>
<td>--</td>
<td>--</td>
<td>7 days</td>
<td>24 t</td>
<td>0 t</td>
<td>2 t</td>
</tr>
<tr>
<td>D supplier 3</td>
<td>February 21</td>
<td>February 24</td>
<td></td>
<td></td>
<td>+ 16 t (4*4t)</td>
<td>4 t</td>
</tr>
</tbody>
</table>

*delivers to the consumer market*

- **If it is possible to harmonize the standards of repairs for each device in the chain, it is possible to make stops for repairs in a synchronized way throughout the chain. In this case, gradual completion of productions should be applied from the most distant link (last supplier), who shall also be the first to start the production after the repair. A simplified example of the coherent maintenance planning in this case is shown in Table 2.**
Table 2. Synchronized Maintenance Planning in the Chain in Case of Harmonization of Standards for Repairs

<table>
<thead>
<tr>
<th>Company (in reverse order in the chain)</th>
<th>The date of the start of the planned stop</th>
<th>The end of the scheduled stop</th>
<th>Time for stock replenishment</th>
<th>The optimal order</th>
<th>Daily production volumes</th>
<th>Lead time in relation to the customer</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>March 14</td>
<td>March 17</td>
<td>3 days</td>
<td>10 t</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B supplier 1</td>
<td>March 9</td>
<td>March 12 (+ 2 days for production + 3 days for delivery)</td>
<td>5 days</td>
<td>17 t</td>
<td>5 t</td>
<td>3 days</td>
</tr>
<tr>
<td>C supplier 2</td>
<td>February 27</td>
<td>March 2 (+ 9 days for production + 1 day for delivery)</td>
<td>7 days</td>
<td>24 t</td>
<td>2 t</td>
<td>1 day</td>
</tr>
<tr>
<td>D supplier 3</td>
<td>February 19</td>
<td>February 22 (+ 6 days for production and 2 days for delivery)</td>
<td>4 t</td>
<td></td>
<td>2 days</td>
<td></td>
</tr>
</tbody>
</table>

*delivers to the consumer market*

Note: The cycle repair is considered 730 hours, 72 hours for the repair, shutdown for the repair is 72 + 24 hours, i.e. 96 hours. Continuous performance of the repair is assumed. The production stop is made on the level of the minimum stocks.

Thus interconnected management system (and planning within it) of the maintenance of production facilities, which are part of the chain operating on the basis of the Quick Response should support both the continuity of the material flow, as well as its efficiency.

**Outsourcing the Maintenance in the Quick Response Systems**

Synchronized maintenance management in the chain may be carried out by the corporate staff, but it does not preclude the use of outsourcing in maintenance.

If the enterprise carries out maintenance on its own, it is necessary to modify the method of internal communication and ensure the necessary exchange of information among individual business units, leading to an effective support of the material flow throughout the chain. It is necessary for the maintenance department to share information important for planning (and realization) of maintenance with other departments and/or process teams in the enterprise. The security requirements must be shared (or transferred) of own business processes, or directly the information may be shared on current and anticipated requirements of customers. This information may already present the possibility of preparation for changes in the customer’s production. If the partners in the chain provide suppliers with the production plans, the maintenance department will also receive information directly usable for management of their own maintenance. The highest effects in terms of continuity of the material flow through the chain and its economy, however, will be achieved through full synchronization of the maintenance work. To achieve maintenance synchronization in the chain, it is necessary for the maintenance departments to share the maintenance plans with suppliers and customers, or cooperate in their development. The previous tables clearly show that full synchronization is achieved if the standards of the repairs are harmonized for each production facility. This means that cooperation must exceed the tactical-operational level and the harmonization must take place also in the strategic level.

All integrations of the systems (including the maintenance systems) at the inter-company level require sharing of information. From this perspective, it is easier to carry out the maintenance by the company’s own employees. This option means less threat of information leakage. However, if the company finds a suitable partner, and he is willing to adapt to the system of cooperation, the maintenance outsourcing is not excluded. It can be used both for the planned repairs and in the case of repairs after failure. The relationship between the two partners must nevertheless be created on the partnership basis and must deliver value to both parties.
It is therefore very important that both parties understand the needs of the other party and that both partners have expressed their willingness for this form of cooperation. The selected partner may also carry out maintenance in other or even in all companies involved in the chain. In that case, he assumes full responsibility for the maintenance throughout the chain.

From the perspective of work with information, there is no big difference between delivering the maintenance on one’s own and application of outsourcing. Transferring and sharing information (between the company’s departments or enterprise/enterprises and the partner carrying out maintenance) usually involves editing the information system. That must allow a quick and seamless delivery of necessary information to the responsible managers and an adequate use for the maintenance management.

Conclusion

Implementation of the Quick Response method to the supply chain requires modification not only of logistical processes in the enterprises to become the members of the chain. Other activities must also be adapted that directly support the material flow through chain. Modifications should also affect the way the maintenance of the production facilities that are part of the chain is carried out. It is necessary that the maintenance system ensures high reliability of the production facility, showing great flexibility in the realization of repairs after failure and presenting minimization of the loss in the production time. High reliability of the production equipment can be achieved by combining modern methods to enhance the performance of maintenance, in particular TPM and RCM. Their application can partially or even completely remove the repairs after failure. The company must however anticipate the possibility of failure and the maintenance system must show such a degree of flexibility that least possible time loss occurs with an accident at the manufacturing facilities. This means that a high level of preparedness must be ensured for repairs after failure, through a policy on workplace, knowledge of required practices and preparedness of the maintenance staff.

To increase the continuity of the material flow through the chain while increasing efficiency, the key is to perform synchronized management of the maintenance work. Cooperation of the chain companies in this area is needed especially in the tactical and operational level. To achieve maximum effect, however, repair standards must be synchronized on which the maintenance management is based. This necessarily means to develop and carry out cooperation in the strategic management of maintenance.

For the actual implementation of maintenance of the production equipment, one can use both the own staff and the maintenance outsourcing. This however represents a higher risk of information leakage and it is necessary to pay close attention to selecting a partner for the implementation of activities and setting conditions of the mutual responsibilities. In terms of the work system, however, there is not much difference between the implementation of maintenance by own or external forces. Both options also require a change in communications and a new information connection.

References