Proceedings of the International Conference on Industrial Engineering and Operations Management
Riyadh, Saudi Arabia, November 26-28, 2019

Performance Measures for Turnaround Maintenance

Umar Al-Turki and Salih Duffuaa
Systems Engineering Department
King Fahd University of Petroleum and Minerals
Dhahran 31261, Saudi Arabia
alturki@kfupm.edu.sa, duffuaa@kfupm.edu.sa

Abstract

Turnaround maintenance is a type of maintenance commonly used in manufacturing continuous industry where plants are completely stopped for a certain period of time to conduct major overhauls and repairs. This type of maintenance is a large project that needs long time of planning and effective implementation. Developing a performance measurement system for controlling the quality of work and continuous improvement is essential for the success of such large projects. This paper introduces a performance measurement system that ties all components of TAM that is based on a system concept.

Keywords
Maintenance, Turnaround and Performance measures.

1. Introduction

Turnaround Maintenance (TAM) or Shutdown Maintenance (SM) is a crucial activity in process industry where a periodic plant shutdown is done to allow for inspections, repairs, replacement and overhauls. TAM is a common practice in many industries, such as chemicals processing and power generation, to sustain a reliable process to satisfy the continuous demand.

TAM projects are huge projects in terms of man power and financial expenditure. The industrial processes that undergo TAM maintenance are often of high value and their maintenance operations are intensive, complex and costly. Therefore, it is vital that TAM is planned and executed effectively. For such a large scale projects, it is highly recommended to include: quality assurance steps of completed jobs and study the feedback for continuous improvement.

TAM projects are, in general, divided into several sequent phases that include validating work-scope, pre-shutdown work, planning and organization, execution, and termination. These phases are cascaded to more detailed steps at each phase to achieve an effective TAM implementation.

The objective of this paper is to design a performance measurement system that would lead to a more effective and efficient TAM process taking into consideration all functional elements that effect or effected by the process. Having a simple but integrated performance measurement system is essential for continuous improvement of the process. The paper is organized as follows. A global system for TAM project is introduced to identify key functional elements of the process that influence its success. Next a performance measurement system is proposed that would capture the most key elements of the process. The paper is then concluded by final recommendations and future suggestions.

2. System view

The system view of TAM that was developed by Al-Turki et al. (2013, 2019) is adopted for developing a performance measurement system that deals with TAM in a global contest. Having a system view of TAM helps in developing integrated plans where all related components are taken into consideration for the benefit of the

whole system. Such view enables the planner to analyze the interrelationship of all parties that play a major rule in the success of TAM execution.

Within the plant (unit) TAM plans are prepared with enough lead time for all preparation, coordination and arrangements to be done before the actual start of execution. All necessary arrangements with external suppliers and contractors are to be done to secure on time delivery of equipment, spare parts, etc., and assuring the availability of the human resources with the right combinations of qualifications and skills. Similarly, financial resources, technical, managerial and IT expertise has to be secured internally for controlling and monitoring all TAM operations. Execution should then start at the pre-set time and continues based on a schedule controlled and monitored by a group of project managers to ensure timing and quality and to be ready for any corrective actions and emerging situations. Success is measured in terms of achieving the predefined objectives in terms of outcomes as well as in terms execution. Success of execution is mostly measured in terms of meeting the schedule within the preset budget in the right predetermined quality. Success of outcomes is usually measured in terms of the having a safe and reliable plant in addition to compounded experience build up for future TAM operations and continuous plant performance improvement.

In a larger context, at the corporate level, the system consists of several plants connected in series, where the output of a plant is fed to the next plant or in parallel where each plant is independent of the other. These plants can be producing raw material or finished products in the petrochemical industry. The plants can also be refineries in the oil industry for any oil producing and processing company. In case of series of plants feeding each other with raw material (sub-products), a buffer or a stack of the material is maintained for continuous uninterrupted production. Final products are passed to external customers without shortage or delay. TAM planning for each plant draws upon a set of resources from different sources, internal and external, such as subcontractors, spare parts suppliers, and technology providers. TAMs are highly labor intensive with various types of skills and capabilities and usually secured through external subcontracting. Spare parts of different technologies are needed to be available at the right time and need to be ordered from different sources taking into consideration lead times and financial commitments. The support and consultation is usually needed to be available from technology providers before, during and after TAM. Figure 1.1 shows all stakeholders of the TAM at the corporate level.

Integrated TAM planning and coordination secures a maximum utilization of resources at the global system level as well as maximizing the global objective of the entire system that encompasses internal and external stakeholders.

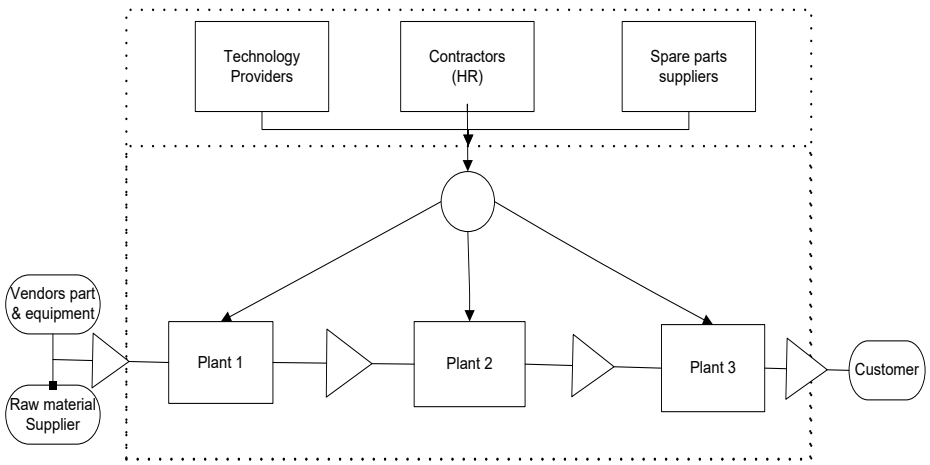

Figure 1. TAM multi plant global system view

For the global system to be integrated for serving the global objective of the corporate, several issues are addressed and built within the system. These issues are as follows:

1. Coordination with supply chain partners

2. Learning process and sharing of best practices with similar industries
3. Performance measurement

A plant undergoing TAM has an impact on, and impacted by, all other supply chain partners including:

- Upstream plants providing raw materials;
- Downstream plants using the plant products as raw materials;
- Vendors providing spares and long lead time items;
- Contractors providing manpower; and
- Final customers buying the plants products.

A formal process for documenting positive and negative experiences during TAM planning and execution should be established. The result should be shared as a best practice document that will enhance the learning process across the organization. Failing to feed back this accumulated experience to the system for future improvements is a major shortage in current TAM practices in the industry. A plat form or a mechanism for sharing best practices across the supply chain should be established and systemized to ensure gaining the expected benefits. This learning process can be extended to other partners (suppliers, contractors and vendors) in terms of the technical know-how for design and technical specifications of equipment and spare parts.

TAM reporting comes after execution when the plant is handed back to the production or operations team in a fit condition so that the return to full production can be accomplished. Lenahan (2006) addressed the importance to capture all of the learning from the TAM event and feed it into the next TAM plan. Houtermans et al. (2007) suggested an excellent time to collect data is during plant turnarounds. They explained, based on the example of a control valve, the role that humans can play to improve the administration of reliability data during plant turnaround. They also presented an example of a decision support model which heavily depends on accurate reliability data. This example demonstrates how a plant owner can benefit from a practical application of reliability engineering. Cormier and Gillard (2009) showed that success of any TAM can be greatly improved, while reducing the associated risks, simply by implementing a rigorous, well-structured knowledge transfer system that communicates the proper process and unit-specific information, specifications and procedures to all those involved. This means that all of the tasks, schedules, priorities, contingencies and perceived risks that should or might occur to a group of workers, who range widely in terms of craft, experience and responsibility, need to be documented, structured and delivered to the appropriate audience through a validated process. In order to be effective, a turnaround training knowledge base should cover the major strategic initiatives, from which a consistent set of learning objectives can be created and assigned.

3. Performance measurement

The overall objective of TAM is to ensure high plant safety, reliability and availability. Therefore, conducting a TAM within schedule and budget may not be enough. In addition to operational measure of budget and schedule, there is need to also emphasize and implement plant effectiveness measures. At the plant level, measures of TAM success have to be set, monitored and utilized for future plans. Such measures should be in line with high level objectives of the organization and agreed upon at the plant level. Having similar measures across the plants within the organization helps in coordination and sharing information across different plants. Including some high level measures that impact the organization helps in optimizing TAM at the global (system) level. Measures should be effectively utilized for improving the TAM process at the plant level and a global level in future plans and executions.

A Supply Chain is a network of organizations that cooperate to maximize the value generated by improving material and information flows among suppliers and customers at the lowest cost and the highest speed. This effort can be measured by sustainable profitability. Although profitability of the supply chain is important, however within the chain may exist some organizations that compete to maximize their return on investment (ROI). This overall objective of the chain may be supported with tactical objectives that include:

- Improving customer satisfaction.
- Improving product quality.
- Minimizing the time required for converting orders into cash.

- Minimizing the total Work-In-Process (WIP) in the Supply Chain.
- Improving visibility of demand by each one of the partners.
- Reducing costs.
- Enhancing services.

In order to assess the strategies for achieving the above objectives many supply chain performance measures are proposed and used. Gunasekaran et al. (2004) proposed a framework for promoting better understanding of supply chain performance measures. Gunasekaran et al. (2001) developed performance measures with emphasis on supplies but he attempted to relate them to customer service. Kleijnen and Smits (2003) provide a survey and a critical review of supply chain management metrics.

In this paper, it is proposed to align the objectives of TAM with the overall system objectives. The following objectives are suggested:

- Maximize productive capacity.
- Improve product quality.
- Enhance equipment reliability.
- Minimizing operation cost, and reducing downtime.
- Cope with legal and safety requirements.
- Enhance cooperation among partners, access and usability of past TAM maintenance knowledge base.
- Improving accessibility and usability of best practices.

The current state of TAM measures is mostly operational to assess conformance to the planned activities. The current utilized measures do not focus on plant performance measures let alone the supply chain measures. The proposed performance measurement proposed here ties the TAM maintenance performance measures to the supply chain overall goal objectives. The following TAM measures are proposed and can be mapped to the supply chain performance measures:

- Information availability, accessibility and usability.
- SM duration
- Reliability within six-month TAM.
- Quality rates.
- Process rate.
- Availability of major machines.
- Spare parts lead time
- Overall equipment effectiveness
- Utilization of resources.

Table 1, Shows the alignment between supply chain measures and TAM measures. The circle indicates a strong alignment or influence of the TAM measure on the supply chain measure while the triangle indicates moderate alignment. The selection of the overall TAM measure must be based on the alignment with supply chain measures.

Table 1: Alignment of TAM and Supply Chain Performance Measures

Measures	Improving customer satisfaction	Improving product quality.	Minimizing the time required for converting orders into cash.	Minimizing the total Work-In-Process (WIP)	Improving visibility of demand	Reducing costs.	Enhancing services
Information availability, accessibility and usability	O	Δ	O	O	O	Δ	O
TAM duration							

			O	O		O	Δ
Reliability within six month TAM		Δ	O	O		O	
Quality rates.	O	O				O	Δ
Process rate.			O	O		O	
Availability of major machines.			O	O		Δ	Δ
Overall plant effectiveness		O	O	O		Δ	Δ
Utilization of resources.						O	Δ

O: Strong relationship. Δ: Moderate relationship

Conclusion:

A performance measurement system is proposed for turnaround maintenance projects that takes into consideration the global business network. The proposed system is based the current practices in the business and the gaps existing that need to be taken into consideration. Mapping between system requirements and the suggested set of measures to ensure complete coverage of all requirements. Further work is needed to be done to ensure the reliability of the proposed system.

Acknowledgements

The authors acknowledge the support of King Fahd University of Petroleum & Mineral through the Deanship of Scientific Research project No. RG-1121-1/ RG1121-2.

References

Al-Turki, U.M., Duffuaa, S., and Bendaya, M., A holistic system approach for turnaround performance management, Maintenance Performance Measurement and Management, MPMM. 2013.

Al-Turki, U.M., Duffuaa, S. and Bendaya, M., 2019. Trends in turnaround maintenance planning: literature review, Journal of Quality in Maintenance Engineering, vol. 25, no. 2, pp.253-271, 2019.

Cormier, B., and Gillard, C.F., Beyond turnaround planning, Petroleum Technology Quarterly, vol. 14, no. 1, pp. 77-81, 2009.

Gunasekaran, A., Patel, C., and Tirtiroglu, E., Performance measures and metrics in a supply chain environment, International Journal of Operations & Production Management, vol. 21, no. 1/2, pp. 71-87, 2001.

Gunasekaran, A., Christopher Patel, C., and R.E. McGaughey, A framework for supply chain performance measurement, International Journal of Production Economics, vol. 87, no. 3, pp. 333-347, 2004.

Kleijnen, JPC, and Smits, MT., Performance metrics in supply chain management, Journal of the Operational Research Society, vol. 54, no. 5, pp. 507-514., 2003.

Houtermans, M., Al-Ghumgham, M., and Capelle, T.V., Reliability engineering & data collection to improve plant safety & availability, 2nd International Conference on Systems, ICONS 2007, art. no. 4196345, 2007.

Lenahan, T., Turnaround Shutdown and Outage Management. Effective Planning and Step-by-Step Execution of Planned Maintenance Operations, Elsevier, Oxford, UK, 2006.

Biographies

Salih Duffuaa is a Professor of Industrial Engineering and Operations Research in the Department of Systems at King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia. He obtained his PhD in Operations Research from the University of Texas, Austin, USA, 1982. My research interests are in the areas of Operations research, Optimization, supply chain, quality control, productivity improvement and maintenance engineering and

management. He teaches courses in the areas of supply chain, Statistics, Quality control, Production and inventory control, Maintenance and reliability engineering and Operations Management. He consulted to industry on optimization of systems that include supply, maintenance and quality control. Dr. Duffuaa is the Editor of the Journal of Quality in Maintenance Engineering, published by Emerald in the United Kingdom and have authored and edited five books.

Umar Al-Turki is a Professor of Industrial Engineering and Operations Research in the Department of Systems at King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia. He obtained his Ph.D. in Decision Sciences and Engineering Systems from Rensselaer Polytechnic Institute in 1994. He obtained M.Sc. in Industrial Engineering and Management from Oklahoma State University in 1989. He served as the Dean of College of Computer Sciences and Engineering, the director of the center of excellence in maintenance research and the head of the Systems Engineering Department. Dr. Al-Turki's research in production planning and scheduling is presented in many international conferences and published in highly prestigious international scientific journals. He is a senior member of the International Industrial Engineering Society and a member of the global advisory board of the Industrial Engineering and Operations Management Society. He was involved in strategic planning for several national and international organizations.