

Design and Development of a Performance Evaluation System for the Aircraft Maintenance Industry

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Abstract – This paper aims at developing procurement Key Performance Indicators (KPI) system for Maintenance, Repair and Operation (MRO) items using a Business Intelligence tool. A set of typical KPI has been established in an aircraft maintenance enterprise through a case study. The result analyzed by business intelligence tools, has become a critical factor in evaluating the success of financial performance, quality assurance, order fill rate, utilization of productivity and development of knowledge hubs in the procurement sector. An effective and efficient procurement strategy evaluation system is proposed in order to resolve corporate problems, with solid supporting data, improved procurement performance management, facilitation of decision making and procurement evaluation by saving resources and time. The significance of this paper is that we delivers a proactive approach by integrating KPI and BI tool for an aviation maintenance enterprise to access comprehensive external data directly, and to visualize the company performance for formulating strategies and analyzing industrial informatics.

Keywords – Key Performance Indicator; Business intelligence; Procurement Performance Management; Aircraft Maintenance

I. INTRODUCTION

Managing procurement performance is a critical task for an aircraft maintenance enterprise, as multiple factors are involved in purchasing maintenance related items, which may lead to high operational cost and long lead time. Aviation companies usually require that the duration of aircraft maintenance, or aircraft on the ground (AOG), should be minimized, with the purpose of returning aircraft to service as quickly as possible. However, the authorized repair and procurement process in maintenance, repair and operation (MRO) under tightened regulation, compliance and authentication by different National Aviation Authorities, is tedious and time-consuming. The MRO process involves accurate planning of the purchase of aeronautical parts and spare parts for aircraft maintenance to fulfill customer requirements. Consequently, the procurement performance is not only from the perspective of co-operation in terms of cost-effectiveness and productivity, but also involves customer expectations on quality, time length of aircraft preservation and cost to achieve the best outcome and

company's goals. Thus, various key performance indicators (KPI) are required to evaluate aircraft maintenance operations.

The range of MRO in an aviation maintenance companies is comprehensive, and requires continuous evaluation by KPI to avoid inaccurate MRO orders such as order sizes and types, at fair and competitive prices. The major challenge in dealing with the MRO procurement process is to draw accurate and proper quotations from MRO suppliers, since MROs have high frequency and great variation [1]. Using the average price of the same components from various MRO suppliers to make decisions for the next purchase is not valid, as the same MRO from different suppliers may offer different lead times, warranties, return policies and after sales service. In addition, MRO supplies usually take up 80% of procurement resources, but constitute 20% of procurement turnover, which results in lengthy procurement procedures and difficulties in administration [2]. The cost of administration may probably go beyond the cost of MRO items, without a complete audit. Accordingly, adopting Business Intelligence (BI) helps monitor the MRO procurement performance with appropriate KPI evaluation, so as to improve the negotiation decisions, monitor the administration performance and enhance the relationship with suppliers.

II. LITERATURE REVIEW

Supplier Relationship Management (SRM) plays a vital role in the procurement process, which involves managing and working collaboratively with suppliers. SRM maximizes the potential value between business activities and all key vendors, which is carried out by the procurement or purchasing department [4]. SRM is able to identifying vendors by understanding the average expenditure per vendor for each procurement category, ranking suppliers by volume and revenue spent in order to improve the value obtained from current suppliers, monitoring the suppliers' performance with quality and on time delivery with the propose of establishing a preferred suppliers list and control the dependency on individual suppliers [3]. Besides, procurement related factors are evaluated by BI tools to diagnose any abnormal performance in manufacturing and to propose strategic scenario management for the acquisition of raw materials, and MRO components. By leveraging an insight into the demand and supply trends in the market, optimal investment in procurement and the prevention of supply

shortage could be accomplished [5]. Users can gather and analyze data from operational systems, like the planning, purchasing, shipping and distribution systems, to gain insight into the business processes, understand procurement issues and predict demand for resources, supplies, inventory and asset [6].

Performance evaluation enables top management to understand the current status and find the root causes for continuous assessment and facilitate decision-making. From the perspective of management, the deployment of the KPI system monitoring by BI tools enhances efficiency and effectiveness of the procurement performance evaluation process in accordance with the implementation of advanced data processing to visualize the operational performance, the decomposition of procurement strategy's goals to quantify the achievement by index and to display all relevant data in a centralized platform [3]. Such typical information helps the company to give reasons for the success and provide a source of communication with lower management for performance evaluation. Furthermore, the built-in data mining tools in BI involve sophisticated statistical and mathematical techniques to summarize the current performance. This is enables making comparison with the past status for reporting crucial event, predict the future trends and simulate different scenarios for long term decisions making for customer satisfaction an better business process management [7].

Although researchers have started to realize the importance of adopting the latest business intelligence techniques for the MRO in the aviation industry, there is

spare research on key performance indicators for practical use and there is a lack of the case studies of how advanced computational technologies can be implemented in the MRO process.

III. PROCUREMENT KPI ANALYSIS ON THE AIRCRAFT ENGINEERING COMPANY

A. Challenges faced by Aircraft Engineering Company

Taking an aircraft engineering companies for a case study, the involved company would like to improve current procurement efficiency through intensifying the procurement KPI analytics system, so as to be able to provide vision and evaluate contract performance. Since the company is a major MRO service provider, which has an aim of supporting its valued customers in ensuring the reliability, availability and unswerving quality of aircraft fleets, including engine services, line services, and freighter conversion. It is challenging for the top management to track and examine the MRO procurement performance, which is related to direct cost. Procurement of MRO supplies in the aviation industry involves a large amount of data records in order to make the corresponding procurement decisions. BI helps to transform the historical data into meaningful information for prediction; prevention of buying inadequate parts; respond proactively to the problem of AOG and implementing strategic procurement to create a valid maintenance service. They expect that BI could figure out a more in-depth analysis efficiently on the current KPI system, so as to answer the frequently ask questions from headquarter, which are described as follows:

Table 1 – The set of KPI on MRO item procurement performance for Aircraft Engineering Company

KPI	Indicator	Description	Objective	Formulation
Cost	Part Price Variance	Percentage price variance between the current unit price and the Last Purchase Order (PO) price for parts	Improving the procurement practices to achieve a more competitive pricing	$\frac{\text{Current Unit Price} - \text{Last PO Price}}{\text{Last PO Price}} \times 100\%$
	Contract Utilization	Percentage by value of purchases made under Quotation, Catalog and Contracts	Accessing the use of efficient contracting mechanism	$\frac{\text{Spend for Quotation, Catalog or Contracts}}{\text{Total spend of all purchase}} \times 100\%$
Quality	Contract Coverage	Percentage by number of purchases made under Quotation, Catalog and Contracts	Understanding the current coverage of contract	$\frac{\text{No. of Quotation, Catalog or Contracts}}{\text{Total no. of all purchase}} \times 100\%$
	Procurement Coverage	Percentage by number of actual usage	Interpreting the successful rate of procurement orders	$\frac{\text{No. of purchase order used}}{\text{Total no. of purchase order}} \times 100\%$
Timeliness	Response Rate	Percentage of successful procurement completed within satisfactory time	Measuring the qualified procurement response rate of communication stage from customers to procurement staff	$\frac{\text{No. of purchase order solved within 3 days}}{\text{Total no. of purchase order}} \times 100\%$
	Emergency Procurement	Percentage by value and number of Aircraft On Ground (AOG), Critical and Replenishment Order	Estimating the ratio of unprofitable and emergency procurement towards all procurement order in dollar value	$\frac{\text{Total value of order in AOG, Critical or Replenishment}}{\text{Total value of all order}} \times 100\%$

Learning	Training Utilization	Percentage of training utilization	Calculating the learning and growth of the employee in procurement department	$\frac{\text{No. of training actually placed}}{\text{No. of planned training}} \times 100\%$
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- 1) Explain the reasons behind the high failure rate of procurement coverage for MRO aeronautical items in the past three quarters.
- 2) Illustrate the root causes of employees' inability to comply with a 2-day quotation response.
- 3) Analyze the impacts on termination of a contractual relationship with a supplier

B. KPI System Analysis for MRO Items

With an aim of measuring and evaluating the procurement service performance, a set of procurement performance KPI is designed specifically for MRO service providers in the aviation industry to match the procurement features and managerial needs in aircraft maintenance. The set of KPI is used to evaluate the performance of the procurement department from four perspectives – Cost, Quality, Timeliness and Learning. All the KPI are shown in Table 1.

C. Analysis on KPI Architecture

Identifying new opportunities and implementing an effective procurement strategy based on new insights can provide a competitive market advantage and long-term stability for a business. BI assists top management in the analysis of current and past activities in the prediction of future trends, and supports managers to design strategy planning and control operational data from functional users via the Operational Database Management Systems (DBMS). The operational data is then transferred to the Business Intelligence Database Management System to report generation and data mining for the top management. These include predictions, what-if analysis and decision-making. Figure 1 shows the working process from frontline operation to the top management of BI.

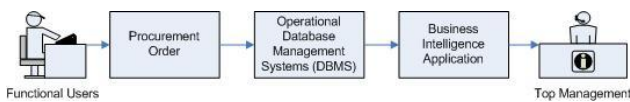


Fig. 1. The Relationship between Operation and BI Applications

IV. PROCUREMENT PERFORMANCE EVALUATION VIA QLIK SENSE

With the implementation of BI tools, the procurement performance analyzes from the results of KPI and identifies the root causes and improvement areas. The three popular and proven BI software systems, Qlik, Microsoft and Oracle, have been evaluated for their respective strengths and weaknesses.

A. Selection Criteria for Business Intelligence Tools on Monitoring KPI Performance

Certain selection criteria for BI tools on monitoring KPI performance are discussed as follows. Microsoft and Oracle require high technological skills and complex modeling design. However, Qlik is the user-friendliest BI tool compared with the others, and is easy to use by simple drag-and-drop to reveal hidden insights from historical data. In addition, the Qlik Sense developer gives more support than Microsoft and Oracle on documentation, online collaboration, tutorials and conferences. Furthermore, the responsive design and free-form exploration of Qlik Sense enables users to evaluate profound knowledge from the KPI performance. Table 2 shows a summary of the comparison between different BI tools.

	Qlik Sense	Microsoft	Oracle
User-Friendly	Ease of use Drag-and-drop	Difficult	Difficult
Support	Strong Qlik Community, documentation, online training, tutorials	Weak	Weak
Complexity of Analysis	Responsive design Free-form exploration	Power Query, Power Pivot, Power View	OLAP
Free-Version	Provided Qlik Sense Desktop	Not yet released	No
Mobility	Yes	Weak	Yes
Interactive exploration	Strong	Weak	Strong

Table 2. Summary of Comparison between BI tools

B. Improvement of KPI System on Managerial Aspect

In order to optimize the procedures on the KPI system to ensure the efficiency and effectiveness of procurement management, high-quality and centralized data mining are developed in the Qlik Sense. The intermediate data transformation system, which is an important process containing Extract-Transform-Load procedures, filters “dirty” data, missing data values, inconsistent data and data in an incorrect format, stores data in the same format in the DBMS and links the data source with the Qlik Sense. The framework of BI tools is shown in Figure 2.

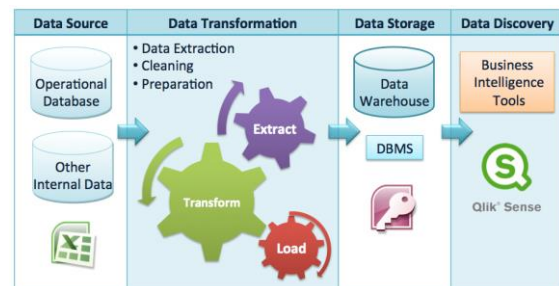


Fig. 2. The Framework of the BI Tools

The snowflake schema shown in Figure 3 is adopted to develop the data model for this study, which is a logical arrangement of relationship tables in a multidimensional database. Buyer, supplier, MRO part, expenditure,

training and Request for Quotation (RFQ) records are embraced in the purchasing order fact table, with order records in a centralized format.

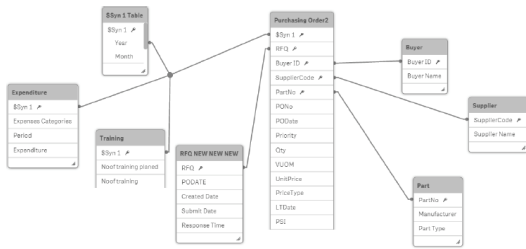


Fig. 3. The Data Model

C. Visualization of Procurement Performance via Qlik Sense

As for resolving the FAQs from the top management, the high quality KPI reports generated from Qlik Sense provide solid analysis and managerial insight in describing statistical indicators and graphical information to enhance the quality of decision-making with integrated KPI BI analytics.

1) Reasons behind High Failure Rate of Procurement Coverage for MRO Aeronautical Items

The top management concerned that there is a high failure rate of procurement coverage for MRO Aeronautical Items in the past three quarters. The company developed a preferred quotation list (PQL) to represent the favourable source of MRO supplies. The major types of MROs for the company are chemical items, raw materials, standard hardware and spare items. The idea of procurement process is to use minimal number of quotation to make a decision on purchasing a single MRO part. It refers to the MRO product knowledge, procurement performance and its learning progress among the procurement department. In Figure 4, true value of KPI refers to positive procurement coverage KPI value, and excluded preferable quotation list (ExpQL) indicates the pre-screened MRO supplier while false value represents 1 minus KPI true value and ExpQL.

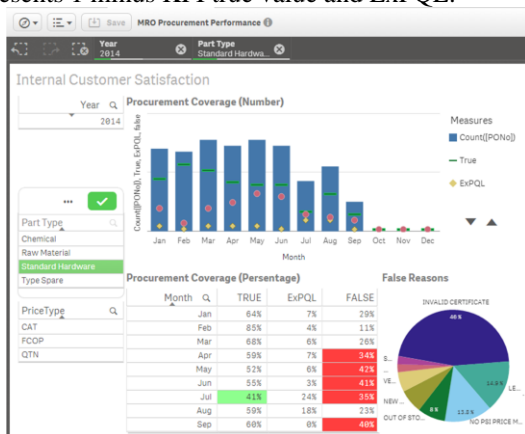


Fig. 4. Platform related on the return rate of MRO Standard Hardware and Relevant KPI

According to the Qlik Sense report, it is found that two-third of the past three quarters accounted for 30% failure of invalid quotation on average. The managers further investigated the problem of higher failure rate of standard equipment procurement and they discovered that the fundamental cause is due to invalid certificates for MRO parts. This is due to airlines being served by different countries that are under various regulations with respect to the controlling by the aviation authority, like European Aviation Safety Agency (EASA) and Federal Aviation Administration (FAA). It suggests that the procurement department could refer to past quotations and make the appropriate MRO order for the sake of reducing procurement failure.

2) Root Causes for Employees' Inability to Comply with a 2-day Quotation Response

The company encountered another problem relevant to the non-conformity of the purchase order regulation. To provide customers with high quality of aircraft maintenance service, the company has designed procurement guidance to their buyers, i.e. that the quotation process be finished within 2 days.

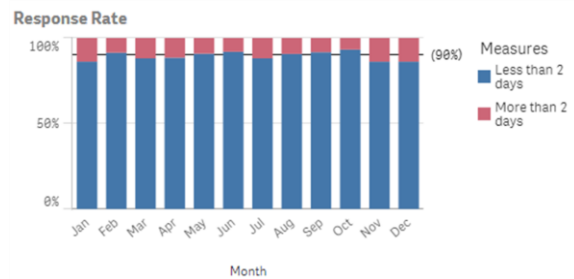


Fig. 5. Average Performance of Response Rate of each month

In the past year, they recorded unqualified response rates on average in January, March, April, July, November and December by comparing the average performance of response rate in each month shown in Figure 5. There were seven employees who were under 50% of the response rate after the review on employee performance appraisal via Qlik Sense in Figure 6.

Buyer Performance			
Buyer Name	Q	Response Time	No. of Response Time
Betty Nichols	Q	5	10%
Jose Dunn	Q	4	100%
Ruth Reed	Q	4	100%
George Walker	Q	4	50%
Pamela Rogers	Q	4	50%
Rebecca Chavez	Q	4	25%
Betty Nichols	Q	4	14%
Brandon Wood	Q	4	13%
Scott Patterson	Q	4	11%
Donna Jacobs	Q	3	100%

Fig. 6. Buyer performance and its KPI

They subsequently discussed with those employees their work difficulties. As a result, the managers found that the critical issue for the declining response rate is the problem in sourcing MRO parts due to inadequate aeronautical knowledge, like latest aircraft regulation policy, MRO

part requirement, and maintenance procedures. Even though the company has provided product training to their staff, they did not have a 100% attendance at product-training courses. The company may provide some incentives to encourage a higher attendance rates in product training. Moreover, staff can refer to the price variance of MRO components to estimate the expected price of the next purchase so that it helps simplify the procurement requisition process.

3) Impacts on Termination of Contractual Relationship with the Aviation Equipment Supplier A

Aviation equipment supplier A, which has under contractual relationship with the case company, is a supplier of spare part constituted around 30% of the total procurement value of the company after analysis by BI tools shown in Figure 7. If the company ends the procurement contract with them, they could rather purchase by quotation or by catalog, but the price and quantity of MRO parts may fluctuate. According to the up-to-date KPI of contract utilization and contract coverage, the company tended to sign contracts with their suppliers recently.

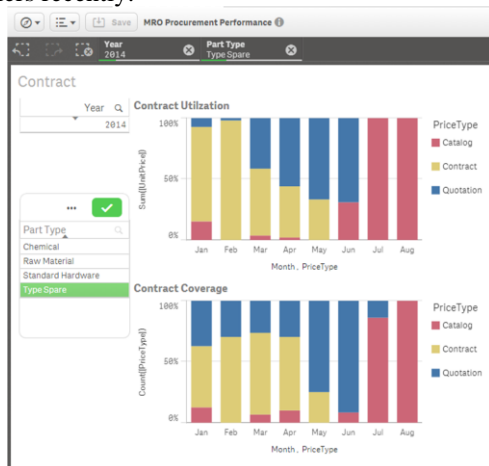


Fig. 7. Visualization of Contract page

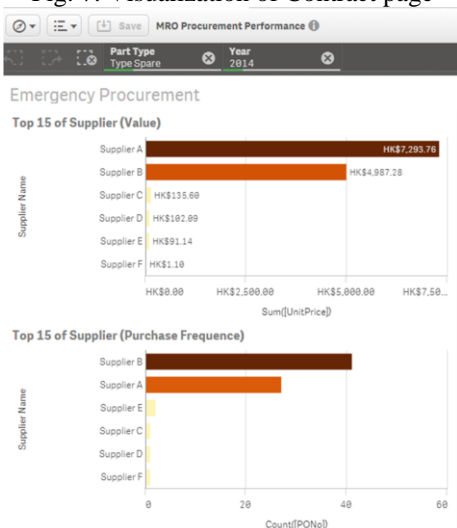


Fig.8. Visualization of Emergence Procurement in Dollar Value and Number of Order

However, the company encountered a problem concerning the contract price that the purchasing price of MROs from supplier A was usually higher than the quotation price. They therefore considered a decision to terminate the contract with them. BI can help evaluate supplier performance in monetary value and purchase frequency. The majority of spare parts purchased in dollar value was from supplier A, at the same time, the report indicated that supplier B was the second largest frequent purchase supplier, shown in Figure 8. In case of terminating contractual ties with supplier A, the company may decide to make purchase from supplier B via quotation.

V. CONCLUSION

This study focuses on a study of MRO performance evaluation by KPI system using BI tools in an aircraft maintenance enterprise. The paper suggests KPI for the MRO in the aviation industry and proposes to use a highly interactive dashboard that spans business-user self-service, because it can enable users to conduct a broader range of analysis, it links with the company performance and develop a long-term strategy procurement policy for optimizing the procurement performance and developing sustainable knowledge growth across the company.

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