REAL-TIME YIELD MONITORING THROUGH ERP SYSTEMS

P. Bhargava[1], J. Sturek[1], J. Peck[2], R. Murcko[1] & K. Srihari[1]

[1]Department of Systems Science & Industrial Engineering
Thomas J. Watson School of Engineering and Applied Science
Binghamton University, Binghamton, NY 13902

[2]Endicott Interconnect Technologies, Inc.
1701, North Street, Endicott, NY 13760

Abstract

Globalization and increased competition requires an enterprise to focus on cost reductions, improved manufacturing processes and higher standards of quality. Effective yield management using Enterprise Resource Planning (ERP) systems is crucial for the success of any manufacturing organization. An ERP system provides the infrastructure for consolidating all business operations by integrating the information flow across functions, including production planning and control. Yield management encompasses continuous process improvement initiatives directed at accurate determination, continuous monitoring and improvement of product yields.

ERP systems are unable to model all of the business processes and hence, enterprises must either settle for the limited options that are present in an ERP package, or must re-engineer the corresponding processes. This research effort is directed at the development of an easy to implement, cost-effective, real-time yield tracking system called the *Closed Lot Yield Tracker (CLYT)*, to be used in conjunction with an ERP system. The *CLYT* continually monitors the shop-floor conditions. In the event of any significant change, the CLYT is accessed and updates the planning modules of the ERP system. Data mining techniques are used to retrieve the product data from the ERP Business Warehouse (BW) module and the Operational Data Store (ODS). The ODS contains information pertaining to the defects that occurred during the product's routing steps, at a production order level, thus facilitating the accuracy of yield measurements. Moreover, *object-oriented* techniques are used to generate increased granular reports for the end-user. The *CLYT* bridges the gap between the ERP system and the actual shop-floor data. This helps in faster and more accurate decision making. This research utilizes relatively new performance metrics for yield management called "*Closed Lot Yields (CLY)*" and "*Actual Cost of Yields (ACOY)*". The proposed metrics could be integrated in the Quality Management (QM) module of ERP systems.

Keywords: ERP Systems, Shop-floor Data, Closed Lot Yields, Yield Management

1. Introduction

Information management has become a critical aspect in today's manufacturing environment. Enterprise Resource Planning (ERP) systems provide a framework for the integration of all the business functions. ERP systems are highly standardized systems that employ a single logical database for the entire enterprise. These systems link the business processes and operating locations so that all functions in the enterprise have access to relevant information, as transactions occur. However, ERP systems have certain limitations in terms of the business processes that they can model. Consequently, an enterprise is faced with a situation wherein it has to either limit itself to the functionality provided by the ERP systems or to modify its own business practices [1, 2].

Enterprises are striving hard for continuous process improvement initiatives to improve yields, regularly monitor product yields, and accurately determine the yields for planning purposes. Effective yield management is critical for the success of any enterprise, especially due to the rapid technological changes in products and processes, high costs of materials and the continuing trend of miniaturization. However, the ERP systems are unable to provide a robust solution to the yield management issues and in some cases Business Process Reengineering (BPR) approaches can be used to alleviate these concerns. BPR revolves around information technology and focuses on the continual refinement of the changing needs of an organization [2, 3]. BPR approaches are used to bridge the gap between the business process and the ERP system.

An Expert System (ES) or a Decision Support System (DSS) are tools of BPR to address the aforementioned concerns. DSS are information systems that support business and organizational decision-making activities. They are intended to help decision makers compile useful information from raw data and therefore identify and solve problems which aids in making faster and more accurate business decisions [4].

The planning and quality modules in most ERP systems lack the capability to use real-time shop-floor data for defect tracking and yield management [2]. This research effort proposes a framework, called *Closed Lot Yield Tracker* (*CLYT*), for calculating industry specific yield performance measures, at a product level on a real-time basis. Additionally, the *CLYT* will also perform defect trending analysis and Statistical Process Control (SPC). The data available in the ERP system data archives (BW) and the real-time shop-floor data is used for this purpose. The *CLYT* uses new industry specified performance measures, namely, *Closed Lot Yields* (CLY) and *Actual Cost of Yields* (ACOY). The proposed architecture could also be integrated with the quality modules of the ERP system.

2. Review of Relevant Literature

Business Process Reengineering (BPR) is a strategic action and requires a clear understanding of customers, market, industry, and competitive directions. BPR and Information Systems (IS) together have the potential to create more flexible, team oriented, coordinated, and communication based work capability. While designing IS for the manufacturing domain, the hierarchy of the decisions made at different junctures must be explicitly considered. Designing information systems (Information Systems Modeling (ISM)) includes the capability of storing and retrieving information for decision making. This is a very important tool while using BPR concepts in an enterprise [5]. It has been recognized that for the successful implementation of integrated information management solutions, corresponding changes in business practices should take precedence. It is a well-recognized fact that BPR is essential for realizing the complete benefit from an ERP system [1, 2, 6].

Yield management initiatives are directed at immediately improving a product's performance within an enterprise. The prime focus of such initiatives is to reduce the scrap (or defects) and the cost incurred by the defects [9]. Continuous monitoring of these defects throughout the enterprise is required for an effective and efficient yield program. The quality of data is critical for the success of such programs. The primary focus of data quality resides with its consistency, accuracy, and accessibility. The ERP systems and the shop-floor data can be used for real-time yield tracking.

Numerous DSS and satellite systems that help enterprises in efficient yield management using ERP packages are well documented in the literature [2, 3, 6, 7]. However, most of them do not effectively use the real-time data present in the shop-floor systems and the ERP systems for yield calculations. Moreover, the industry defined metrics (such as CLY and ACOY) are not recorded for in the aforementioned systems, thus forcing the end users to calculate these metrics manually. This research, on the other hand, integrates the shop-floor systems with the enterprise planning systems, facilitating the use of real-time defect data for making accurate and faster decisions, while accounting for the yield metrics. This research effort uses an architecture that integrates the shop-floor data with ERP systems for tracking defects in the production line for estimating the instantaneous yields and the CLY - a unique approach in this area.

3. Problem and Objective

Most enterprises that use ERP systems struggle to integrate the functions of its Quality Management (QM) module with real-time data collection, analysis and reporting. The minimal functionality and cumbersome user interface available in the QM module make the task difficult, if not impossible [10]. This research effort is directed at the development of the *Closed Lot Yield Tracker (CLYT)*, a DSS which can be used in tandem with an ERP system for real-time yield tracking.

This research endeavor attempts to overcome certain limitations in the QM module of an ERP system, for enhanced decision making. The proposed framework uses the shop-floor data through the ERP system to record defects in the production line and then calculates both instantaneous yields and CLY, in addition to monitoring product defects, on a real-time basis. SPC techniques are coupled with real-time data from the ERP systems aiding a comprehensive overview of the inherent problems in the process and details of where the defects occurred. The architecture also uses industry specific performance metrics for yield management, namely, *Closed Lot Yield (CLY)* and *Actual Cost* *of Yield (ACOY)*. These newly defined metrics, which are not covered by the ERP system, would lead to more representative product yields.

4. Methodology

The methodology and the scope of the *CLYT* is presented in Figure 1. The data from the shop-floor is extracted through the Production Data Acquisition (PDA) module, into the ERP system data warehouse. The *CLYT* framework then retrieves the relevant data from the data warehouse for reporting the defects and calculating the yields. Yield tracking is performed at three levels of granularity, namely, sector specific product yield, defect specific product yield and sector-defect specific product yield.

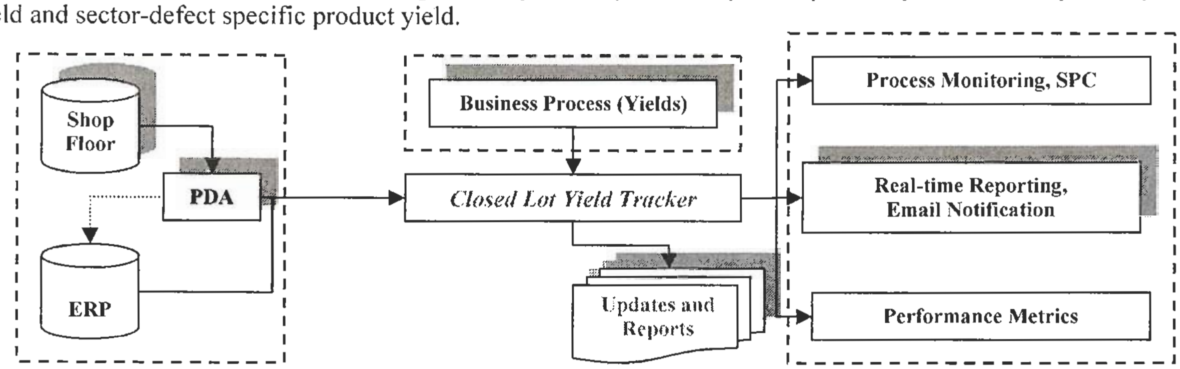

Figure 1 - Scope and Framework of the *Closed Lot Yield Tracker*

The *CLYT* uses the new industry specific performance measures for yield management, namely, *Scrap Not Rung* and *CLY*. The mathematical formulations of these performance measures and other functionalities of the *CLYT* are discussed in detail in Bhargava et al. [10]. This paper would focus predominantly on the architecture of the *CLYT*.

4.1 Software Architecture

The *CLYT* has been designed to provide the yield tracking and inference mechanism. Figure 2 illustrates the architecture and the logic flow of the *CLYT*. The design phase involved two components namely, the database (tables and their relationships) and the design of the Graphical User Interface (GUI). The inference engine acts directly upon the rules stored in the knowledge base and archived data to calculate the CLY and the ACOY. The logic for the rule base is developed using Microsoft® Visual Basic for Applications (VBA) language. *CLYT* has been developed using Microsoft® Access. The shop-floor data, which has the current state of the production line, is retrieved through the PDA module. The *CLYT* is a relational database, with tables and queries, based on the data that resides in the ERP business warehouse. It also has built-in real-time reporting functions. A batch job is run to extract this information from the ERP system, transform it into the required format, and stores it into the *CLYT*. Typically, the data from the PDA module would encompass the information at a product-sector scrap quantities and product-sector-defect scrap quantities level. This would help achieve more accurate and realistic yield calculations.

Two transactions, ODS(1) and ODS(2), were developed in the ABAP® programming language for obtaining the relevant information on a real-time basis. The logic and the program are outside the scope of this paper. The functions of the two transactions are listed below:

1. ODS(1): This transaction retrieves the 'good' (stocked) quantity and the scrapped quantity as the product passes through various sectors (group of workcenters that perform identical operations) at a production order level.
2. ODS(2): This transaction retrieves the defect quantity, the defect description, defect code, and the ACOY at a production order level.

The *CLYT* has two main modules. The first component uses the ODS(1) transaction and determines the start quantities of products based on the stock quantities and the scrapped quantities. The CLY is determined and reported through this component. The output also feeds the second component along with the ODS(2) transaction. The second component will determine the percentage scrap of defects in addition to the ACOY. The feedback from both components is sent to the *CLYT* engine, wherein the user can view any significant change in the yield metrics over the chosen time period. Any updates that need to be reflected in the planning modules of the ERP system can be accomplished through a batch program.

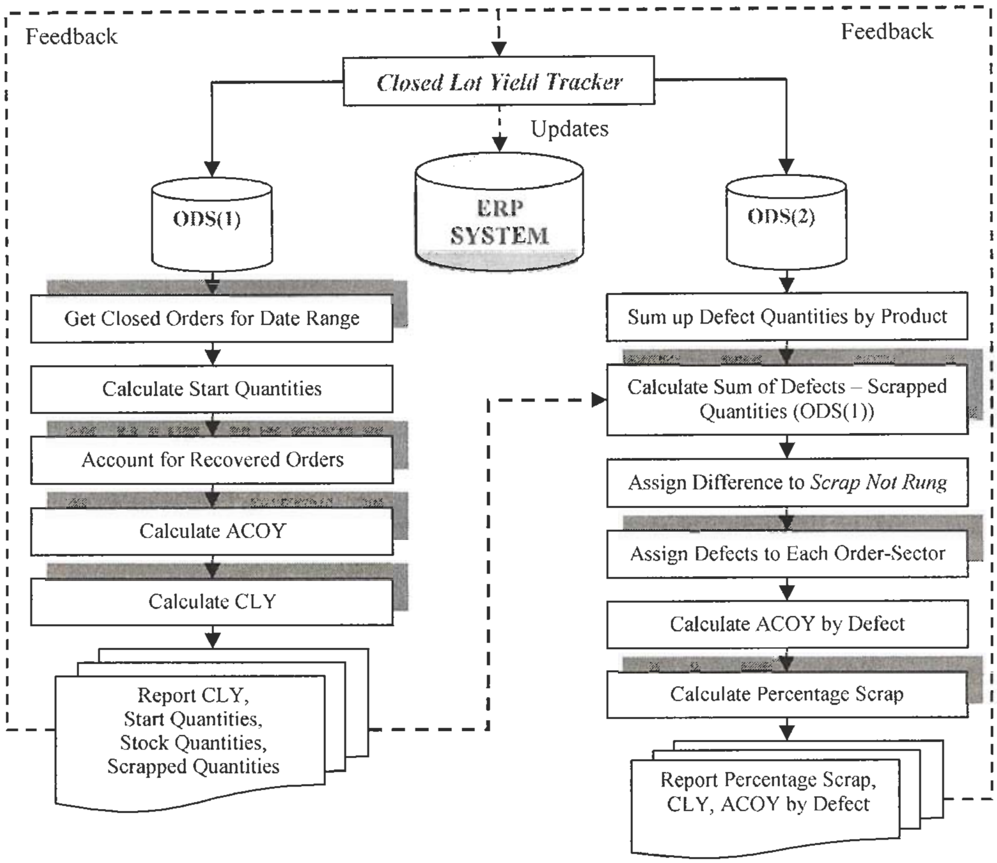

Figure 2 - Architecture and Logic of *Closed Lot Yield Tracker*

4.2 Module 1: Calculation of the Closed Lot Yields

It is observed that the QM modules in the ERP system calculate only the instantaneous or the Open Lot Yields (OLY). The OLY does not represent the true picture of the product yield, especially in the event of low or fluctuating volumes. CLY, on the other hand, is a measure of the release yield over a period of time. Additionally, the CLY is calculated once the products are completed and are ready to be shipped. However, it should be noted that the CLY will complement, and not replace, the OLY for planning purposes. Numerous attempts to estimate the CLY have been conducted in the past [2, 7, 8, 10]. However, all previous attempts did not account for the 'unrecorded' defects in the manufacturing line, thus resulting in an inaccurate estimate of the CLY. CLY is the ratio of the number of stocked (good) products to the sum of the start quantities, defect quantities, and the unrecorded defect quantity [10].

The information retrieved from the ODS(1) transaction feeds the *CLYT*. Each record in the *CLYT* will contain the start quantity, good quantity, scrap quantity, stock yield and actual yield. Additional information, such as order number, material, product code, business line, customer name, material description, release yields and yield targets for that specific order are reported. It was observed that the ERP system does not include the 'recovered' orders in the calculation of the CLY. Hence, the logic in the ERP system had to be reengineered to account for the recovered orders. The pseudo code to calculate the CLY and cost of yields is shown in Table 1.

4.3 Module 2: Defect Tracking and Analysis

Once the CLY and the ACOY are calculated and reported, every occurrence of any defect needs to be assigned to a defect code and description. This would facilitate *root cause analysis* and other yield enhancement measures. The relevant information to estimate the percentage defects is obtained from the ODS(2) transaction. As mentioned earlier, ODS(2) is used as the front-end for operators to record the occurrence of any defective product in the shop-floor.

Step	Calculation Description
1.	Retrieve all stocked or closed orders.
2.	Check for the production order type (Normal or Recovered).
3.	Determine order type.
3.a	Normal Production Orders: Calculate the start quantities and subsequently, the stock yield, for all products. $StartQuanity = GoodQuantity + ScrapQuanity$; $StockYield = GoodQuantity / StartQuantity$
3.b	Recovered Production Orders: In this case, start quantity and stock (good) quantity are the same. Hence, the stock yield would be 100%.
4.	The above calculated quantities in step 3 are combined to obtain the costs of yields associated with the orders.
4.a	The cost of yield for the normal production orders can be calculated as: $ACOY_{normal} = (CostofYield) \bullet ScrapQuantity$
4.b	The cost of yield for the recovered production orders can be calculated as: $ACOY_{recovered} = Max(CostofYield) \bullet GoodQuantity$

Table 1 - Pseudo Code for CLY and Cost of Yields Calculations

It has been observed, however, that there is a difference between the total number of products that are scrapped and the 'stock' values in the ERP system, resulting in a discrepancy in the calculation of the product yields. *Scrap Not Rung* is a metric that captures this difference in the shop-floor stocks and the ERP stocks, in order to calculate the start quantities. The algorithm of this metric is discussed in Bhargava et al. [10]. Table 2 displays how the code for defect tracking is calculated.

Step	Calculation Description
1.	Obtain the stock quantities, scrapped quantities and start quantities from the CLY calculation module discussed in Section 4.2.
2.	Import the defect information from the ODS(2) transaction.
3.	For each closed order, check whether the total 'defect quantities' in ODS(2) and the scrapped quantities in the CLY module are equal.
3.a	*Sum of Defects in ODS(2) equals the scrapped quantities in CLY module:* Calculate the percentage scrap as the ratio of defect quantity to the start quantity and the ACOY as the product of the defect quantity and the ACOY at the sector.
3.b	*Sum of Defects in ODS(2) is less than the scrapped quantities in CLY module:* In this case, the difference between the total scrapped quantities and the sum of defects in ODS(2) is determined as the *Scrap Not Rung*. The ACOY is set to the maximum of all the costs of yields for the specific order.
4.	The percentage scrap and the ACOY are then calculated and reported.

Table 2 - Pseudo Code for Defect Tracking

4.4 Reporting Capabilities

The *CLYT* has numerous customizable reports, which have been developed using Microsoft® Access. The main reports that are generated by the *CLYT* are discussed in the following sections.

1. *Release Yield versus Actual Yield*: In this report, the release yield is compared against the actual yield for the products chosen by the user, for a specific time period. The report would aid yield managers to further investigate the variation of the overall product yield over a period of time.
2. *Actual Cost of Yield (ACOY) by Business Lines*: This report presents the Total Actual Cost of Yield (TACOY) incurred by each business line. It helps the management to identify the areas of improvement in the enterprise.
3. *Pareto Analysis*: This analysis was performed with respect to defect types for the period of interest. There are two types of analysis that were conducted: (i) 'defect type' on the horizontal scale and 'percentage scrap' on the vertical scale and (ii) 'defect type' on the horizontal scale and 'cost of scrap' on the vertical scale.
4. *Scrap Not Rung*: The unrecorded scrap quantities are reported by the product across the chosen date range.
5. *Defect Trend Analysis*: This report shows the percentage of defects that occur at each sector for a product or group of products across the chosen date range. This report aids in trend analysis and also plots control charts to

check if there is an "out-of-control" situation in the line. In such an event, an email notification is sent to the respective process engineers. Figure 3 highlights a few of the above mentioned reports.

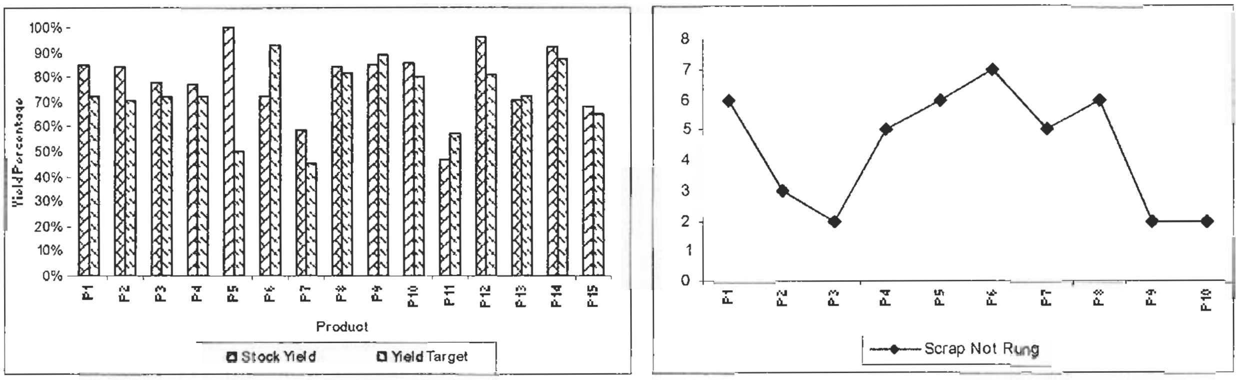

Figure 3 - *Closed Lot Yield Tracker* Reports

5. Conclusions

This research effort was directed at the development of a DSS, '*Closed Lot Yield Tracker*', which would complement the QM modules of the ERP system. One of the main contributions of this research is the use of shop-floor data in tandem with the planning and quality models of the ERP system for real-time decision making. BPR approaches are used to bridge the gap between the ERP system and the yield management business process in the enterprise. Moreover, the QM modules of most ERP systems have certain deficiencies with respect to efficient yield management. Utilizing the new yield metrics, such as *Closed Lot Yields (CLY), Actual Cost of Yields (ACOY)* and *Scrap Not Rung,* would help provide an improved accuracy of yield measurement and defect trends. The framework developed in this research could be used for both real-time as well as long-term yield monitoring, in addition to online process control – a unique feature of this research.

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