Design & Development of Collaborative Workflow for Lean Production in a Repair & Overhaul Industry

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Abstract: - Aerospace fuel nozzles maintenance, repair and overhaul operation is a dynamic process as the work flow is unpredictable. Further detail checking and analyzing on defects are needed in order to determine the workflow. The traditional paper based of work in progress information had been implementing as to manage the nozzles production. However, paper based of work in progress information is inefficient in dealing with these unpredictable and complex workflows. There is a probability of entering or recording the error information when it is in paper based system. This wrong information will cause problem in production line as the results are inconsistent. Furthermore, this inaccurate result will lead to difficulty in tracking the nozzles. Excessive time is needed and wasted in indentifying and correcting the errors. Hence, an electronic based of work in progress system is apparently required as to overcome the shortcoming of the paper based tracking and also to enhance the efficiency of production line. This paper will describe the configurable and customizable work in progress tracking system as a mean to improve over the traditional paper based system.

Key-Words: Work Flow, Configurable, Tracking System

1 Introduction

"Lean Production" has been widely used but not in the aftermarket industry as yet. This paper is to study one of a leading companies in repair and overhaul of fuel nozzles in Asia Pacific. The intensive study will be conducting on improvement of processes by bridging the lean concept with technological innovations to enhance product and service value to their customers.

The maintenance, repair and overhaul (MRO) of aerospace fuel nozzles is a part of aircraft maintenance, repair and overhaul industry. The purpose of this MRO industry is to fix and repair any sort of mechanical or electrical device which is out of order or broken. In this paper, the device to be maintained is the aerospace fuel nozzles. Maintenance, repair and overhaul operation of the fuel nozzles is a dynamic process. MRO activities such as testing and repairing will be carried out with the intention to retain the defect nozzles. The repair activities can be different based on the nozzles condition. Different activities will be carried out in different stations. Therefore, the status of the nozzles will be updated each time the activities finished. These updates will ensure the proper operation and maintenance of nozzles and also to enable the company to trace the status of the nozzles. Hence, the accurate information of the nozzles is vital as to enable company to track the nozzles efficiently and avoid errors in production line.

According to [1], the importance of work in process (WIP) for capacity requirement planning had been highlighted. Accurate work in progress information is definitely needed for the capacity requirement planning as to improve the production line performance. Hence, lots of optimization techniques such as Classical Planning, Hierarchical Task Network Planning and Decision –theoretic Planning had been proposed. However, based on [1], these techniques only focus on the optimization aspect of the process and assume that all the relevant information is available. It also mentioned that obtaining the WIP information is not as straight forward and therefore a real time WIP system in production line is suggested as to enable company to have real time control of their production process. Literatures above had shown the importance of WIP

information in production line. With real time WIP, the company is able to manage and control the production flow efficiently. This paper will discuss a study done for an MRO company which intends to implement a WIP tracking solution. In this paper, a solution of implementing real time WIP tracking system will be discussed as for overcome the shortcoming of the previous paper based WIP information.

1.1 Motivation

A generic work flow diagram which indicates operation of the MRO company we studied is shown in Figure 1. The operation of the company starts by receiving the incoming product, nozzles. When the nozzles are received, paper travelers will be generated and issued. These paper travelers that carried the product order information will route throughout the entire production process. The main production processes are Repair, Overhaul and Checking and these processes will be carried out in different work stations. During the production process, when a defective part of the product is identified, the part can either be scrapped or reworked. When the defective part is identified, another documentation which records the distribution of the products to or from the production flow, called MDR will be issued together with the original paper travelers. After the defective part had been inspected and analyzed, a rework traveler will be issued and the nozzles that had been diagnosed which will then enter again into the main work flow for further processing. Finally the last process is to handle and export the finished product.

Problem occurs during the production process as each operators need to manually update the status of the product by handwriting. The total amount of the processed product is actually recorded as each time the production process carried. However, based on the production work flow, the defect product will have to move to another process either reworks or scraps, which also means the products work flow, is alternative. Therefore, calculation of the total amount of processed nozzles needs to be performed by the operators. This will be increased the probability of recording the false information due to error in calculating and wasting time as the operator need to check their calculation and also need to ensure that they record under the correct processes. Therefore, a real time WIP information system is suggested as to enable the operators to record the WIP information efficiently. This will help the operators to be more concentrate in their main tasks rather than wasting their time on calculation.

Another issue that needs to be concerned is the status of the products. When there is a defective part of handling the nozzles with the same product order can be scattered around different stations. This is because only the defective nozzles will be rejected or reworked until it meets the quality requirements while the other nozzles with the same product orders can move forward to the next process. Problem occurs when the company needs to trace the nozzles. It is totally inefficient as the company needs to track the nozzles by searching through each work stations. This situation occurred when there is no proper recording of the WIP information. Therefore, real time WIP tracking system is proposed as to overcome these problems.

2 Literature Review

Due to the advanced technology, RFID technology is moving toward the low cost solution for many applications [9, 13] especially it addresses security issues [8]. RFID technology had been implemented in manufacturing industry as to gain visibility on its production floor and also control and monitor the status of the work in progress [1] and [2] had been using RFID technology in their tracking system [7]. According to ABI research [6], "*MRO is Major RFID Opportunity for Aero and Defense*". They predicated that RFID technology applies in Aero and Defense will reach $2 billion in 2011. This WIP tracking solution requires RFID tags and RFID readers as to perform the data collection and updates. The RFID tags are used to attach on the products. This RFID tags contain the product information which can be scanned and transmitted into the RFID reader.

The advantages of using RID are as follows [11, 12]:

a) does not need to have line-of-sight reading,
b) can handle and hold more data than bar codes,
c) can be changed or added to as a tag passes through specific operations or different kind of operations or steps,

d) are more effective in harsh and tough environments where bar code labels have problems

The disadvantages of using RID are as follows [11,12]:

` a) RFID tags are more costly as comparing with bar codes

b) RFID signal may subject to interference with some materials

c) RFID tags can not be detected in the certain environment

d) RFID standards are still not finalized yet.

The usage of RFID technology plays an important role in the logistic environment [14]. However, RFID technology is not suitable in our research as our product; nozzles will be going through operations such as chemical testing where the RFID tag can be damaged under this condition.

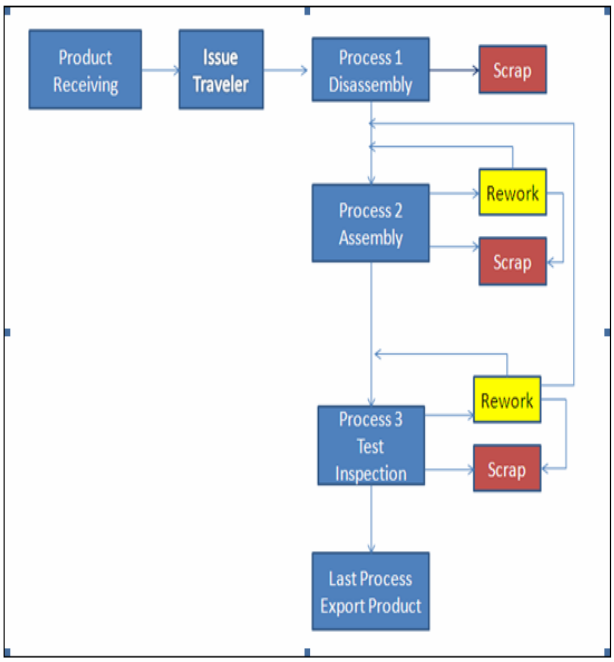

Figure 1 Generic Work Flow of MRO Operation

3 Research Methodology

This project is divided into 3 phases as shown in Figure 1.1.

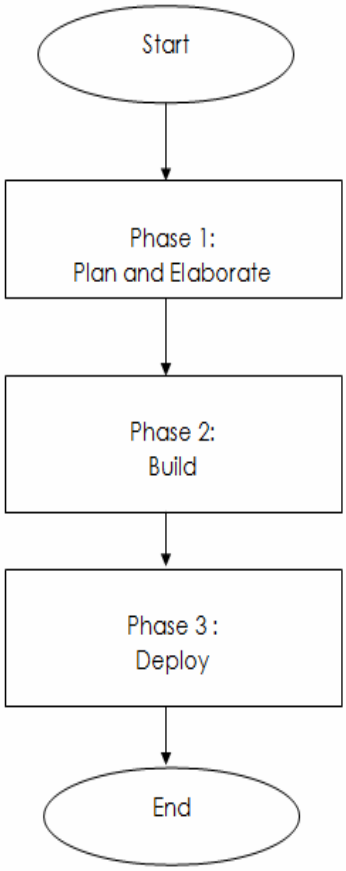

Figure 1.1: Flowchart of the research methodology

Phase 1: The activities of the Plan and Elaborate

- A study of existing literature on lean principles and practices and collaborative workflow;
- Producing a draft plan of the project;
- Defining an initial model;
- Building some initial prototypes.

Deliverable:
A literature review on the latest technologies in lean principles and practices, collaborative workflow, draft project plan, initial model and prototype are produced.

Phase 2: The activities of the Build phase (iterative and incremental)

- Refine project plan;
- Requirement capture to define a model of the collaborative workflow;
- Produce an analysis model of the collaborative workflow;
- Design of collaborative workflow;
- Implement the collaborative workflow;
- Testing, integration and evaluation of the whole system;
- Reports documentation.

Deliverable:
Collaborative workflow

Phase 3: Activities of the Deployment phase

- Deliver user guide and help guide;
- Deploy the resulting software system;
- List any problems and enhancement;
- Review reports and models;
- Training.

Deliverable:
User guide, software, reports, models

4 Proposed Solution

Real time WIP system is being proposed as to provide the view of the updated products information in production line and the most importantly is to enhance the management of the process flows. Real time information is an important as it reflects the real situation of shop floor. Management level will definitely need the updated and accurate information from shop floor as for their decision making of operations and manufacturing control. The importance of operation management and the decision support system for manufacturing control are discussed in [3] and [4]. Hence, the actual performance and the updated WIP information are needed for the operation management. The realization of real time management of shop floor WIP is greatly discussed in [1] and [5]. However, they are implementing RFID technology in order to achieve the real time WIP tracking. Rather than RFID technology, we proposed an affordable and an efficient approach to replace the paper based manual WIP tracking.

In order to enable the users to access the accurate WIP information, WIP terminal application is suggested to be built strategically in the selected workstation. Currently, the operators need to proceed to a board in order to update their job status. With the terminal applications reside in their work station area, it will create a convenience working area and also help to optimize the production process. The terminal applications are created as to replace the existing paper based WIP. The operators are required to login as to use the terminal applications for updating their jobs. This is to enhance the production line management as the company can view or trace the products which are operated by the operators. The operations are being created in the database and the list of operations that can be performed by the operator had been configured in the terminal applications. This is to avoid situation which out of operations sequence occurs. One of the significant concepts which is highlighted in [5] that, adaptation of flexible and reconfigurable manufacturing cells or lines is efficient in overcome the shortcomings of job shops. Hence, flexible and configurable concept is adopted in our approach as to meet the company requirement changes and its growing business needs. The company's product, service, model, process or operation will be considered and required to be configurable. In order to achieve the configurable of the list, configuration management is released to the authorized employee. Figure 2 below shows the configurable list that is being developed in web based system.

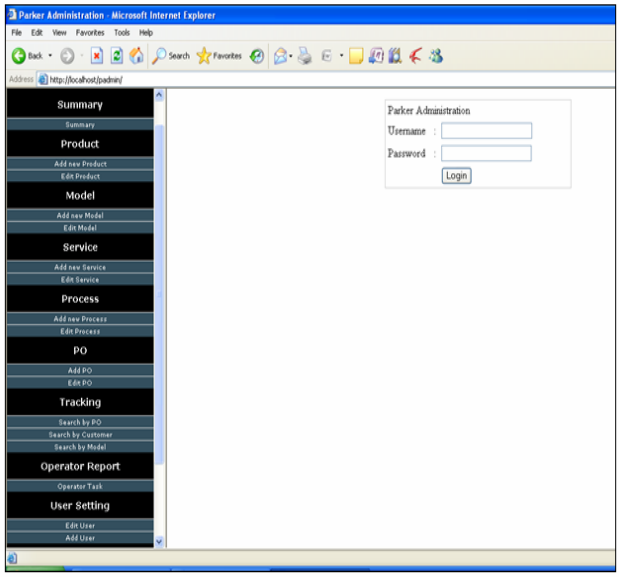

Figure 2 Administration Web Page

As to provide the real-time WIP information, data consistency is important. All the data that is updated via the terminal application is directly updated to the database. This is to ensure that every employee is viewing the same pieces of information. This information is crucial in providing the updated reports. This updated information will ease the tracking jobs. As mentioned above, when the products need to be reworked or scrapped, the product with same product order will be scattered in different stations. Hence, based on this real time information, the rework part can be easily and quickly located without going through station by station. A web based application is proposed as to enable the employee to track the nozzles status. It is customizable where the nozzle can be searched based on product order, model number, part number or customer order. Alarm is the indication for tracking each task or process is in schedule.

The purpose of this proposed real time WIP tracking is to allow the employee to trace the status of the specific nozzles as to report to the management level or customer. This also shows that the management levels wish to predict and ensure that the products can be delivered on time. Therefore, another alarm application is being suggested as a solution for this challenge. Alert will be generated and send to the management level and operator as a report for follow up. The operators also can choose the urgent product to process first as to avoid late delivery to customer.

Figure 3 is the WIP table that generated by the system to enable the management and staffs to track the nozzles status effectively.

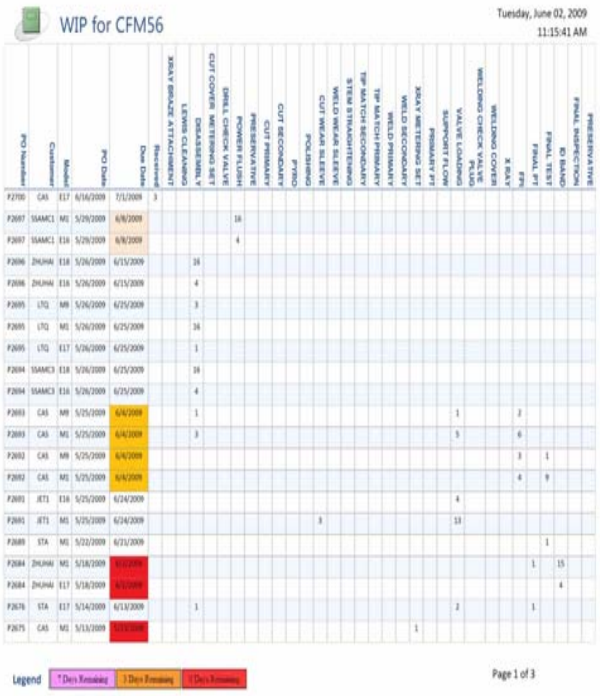

Figure 3 WIP Table

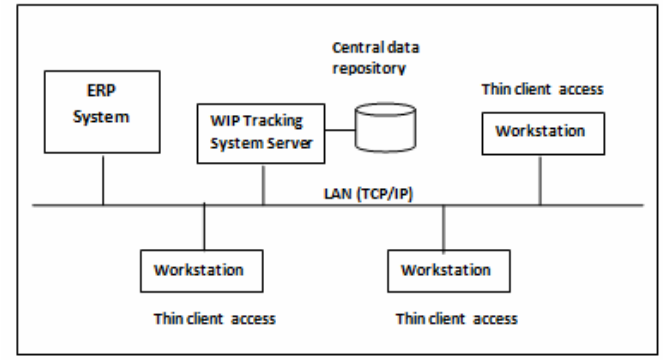

Figure 4 Hardware System Deployments

5 System Development

The WIP tracking system is designed to work as a complement to the company's existing ERP system. The current ERP system captured only the data at the beginning and the end of the production line. It does not monitor the work in progress processes that are vital for job planning and prompt customer service. The WIP system will get the input from the ERP system, where it downloads the new purchase order information from the ERP server every 30 minutes. It then creates the WIP records for each purchase order. The operators need to update only WIP status of the nozzles that they process. Upon completion of inspection and repair, he updates the quantity of nozzles for the downstream process. For nozzles that have been sent to the end of the production line, the WIP tracking system will update its database by sending query to the ERP database. In other words, the operators only update the work-in-progress status in the WIP system. The input and output of the WIP data are updated automatically by the system by communicating with the ERP system at a specific interval.

The real time WIP tracking system had been developed using client-server architecture. Figure 4 shows its hardware system requirements. A minimal database and code maintenance is required in developing this system. An open source Mysql database had been chosen to reside at the server while the client program was written in Microsoft Visio Studio .Net in C# language. The primary database table design is shown in Figure 3. WIP_PRODUCT_# table is dynamic created based on the Product table where each of the products will create a separate WIP_PRODUCT_# table. For example Product with product id = 1 will have WIP_PRODUCT_1 and respectively. Process fields for each WIP_PRODUCT_# table will refer to the Product Process table. Dynamic creation of WIP_PRODUCT_# enables the system easy configurable and customizable especially for non-IT user. Configuration can be made easily via web configuration management system.

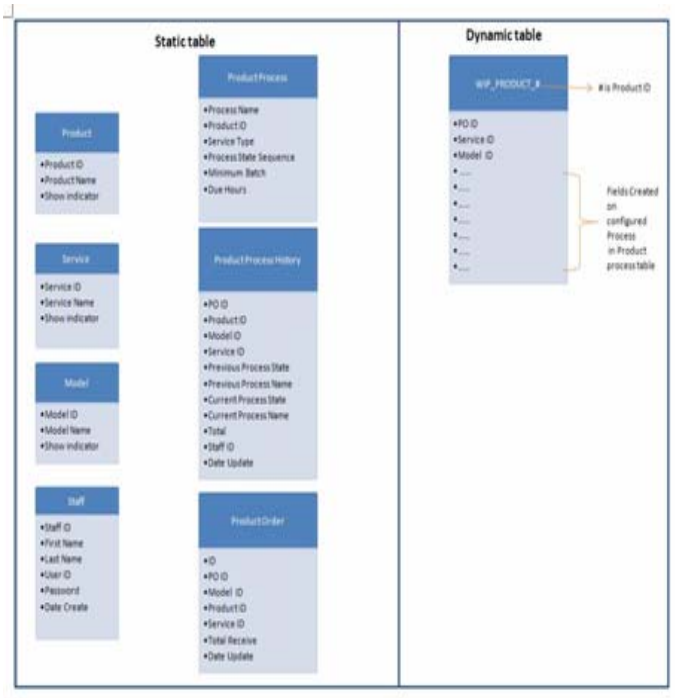

Figure 5 Database Table Design

6 System Implementation

Following the implementation of the WIP tracking system, the following workflow is required to be performed by the operator to ensure that the WIP data is captured and updated.

- Upon completion of repair and inspection, he logins to the WIP system, enters the PO number, select the model and service type, select the process that he has carried out, enters the number of nozzle(s) he has processed and select the downstream process that he is going to hand over the nozzle(s).

- If rework is required, instead of selecting the downstream process, he needs to click on a Rework button then only he is able to pass the nozzle back to an upstream process.
- If a nozzle is unable to be repaired and need to be scrapped then the operator has to click the Scrap button and enter the MDR number.

The system consists of three parts – the terminal application, the configuration manager, and the report generator. The terminal application is a Windows application with graphical user interfaces. Users only need to key in their ID, password and number of nozzle that they are going to process. The work-in-progress status updates are carried out through button clicking and only the applicable processes button are enabled to prevent data entry error. Apart from that, there is a Back button located at the top right corner of the application that allows user to go back to the previous screen.

The configuration manager is a user friendly web based application. User can update the database records through simple GUIs elements such as window, menu, hyperlinks, drop-down list, check box, text box and buttons.

This report generator is developed using Microsoft Access, which is a software that the user familiar with. A report is generated in seconds based on user selection.

Delayed orders are highlighted in red in the Terminal Application as well as in the Summary section of the Configuration Manager. User may click on the PO number to view its progress history. In the Terminal application, Pos that are close to the due date (7 days or 3days remaining) also highlighted in pink and orange respectively.

The report system enable the user to view the number of nozzle completed by the operator at a daily, weekly, monthly and yearly basis. It helps the management to monitor the operator performance.

6.1 System Testing

Table 1 shows the test cases for application module that handed to the user during the User Acceptance Test and all test cases has been passed.

Table 1 : Test Cases for Application Module

Test Code	Test Description	Expected Result
TA-001	Module: User Login -Wrong User Name	System do not have this user ID
	Module: User Login -Correct User Name	Password Screen
TA-002	Module: Password Login -Correct Password	PO Screen
	Module: Password Login -Wrong Password	Wrong Password
TA-003	Module: PO Entry -Valid PO	Model Screen
	Module: PO Entry -invalid PO	System do not have this PO
TA-004	Module: Model Screen -Select Model	List of Model Available
	Module: Model Screen -Skip select Model(Only have 1 model)	Proceed to Service Screen

	Module: Model Screen -no Skip select Model(Only have 1 model)	List of 1 Model Available
TA-005	Module: Service Screen -First time select services	List of Service(OH,CCT,REP) all enable
	Module: Service Screen -Second time select services	List of Service(OH,CCT,REP)enable service in WIP only
TA-006	Module: From Process Screen -Select Process	List of process available for correct product, service, total
	Change Service Type OH-Repair Change Service Type OH-Repair	
TA-007	Module: Total Nozzle -Valid Total Nozzle	To Process Screen
	Module: Total Nozzle -invalid Total Nozzle	Please enter number of nozzle between 1 to (Total Nozzle)
TA-008	Module: To Process -Select To Process	Confirmation Screen
TA-009	Module: Scrap -Enter valid MDR no in range of 1-6	TO MDR Screen
	Module: Scrap -Enter valid MDR no in range of 1-6	Maximum MDR is 6 digits
TA-010	Module: Confirmation - Confirm	Record is updated successfully
	Module: Confirmation - Cancel	Back to Process Screen

Table 2 shows the test cases for administrator configuration module that handed to the user during the User Acceptance Test and all test cases has been passed.

Table 2 : Test Cases for Administrator Configuration Module

Test Code	Test Description	Expected Result
AC-001	Module: Product -Add Product	New product is added.
	Module: Product -Edit Product	Product name is edited.
AC-002	Module: Model -Add Model	New model is added.
	Module: Model -Edit Model	Model name is edited.
AC-003	Module: Service -Add Service	New service is added.
	Module: Model -Edit Service	Service name is edited.
AC-004	Module: Process -Add Process	New process is added.
	Module: Process -Edit Process	Product name is edited.
AC-005	Module: PO -Add PO	PO is added
	Module: PO -Edit PO	PO is edited.
AC-006	Module: Tracking -Search by PO	PO detail are displayed
	Module: Tracking -Search by Customer	Product Progress History of Selected Customer is displayed
	Module: Tracking -Search by Model	Product Progress History of Selected Model is displayed
AC-007	Module: Operator Report -Operator Daily Performance	Operator Daily Performance Report is shown
	Module: Operator Report -Operator Monthly Performance	Operator Monthly Performance Report is shown
AC-008	Module: User Setting -Edit User	User details are edited.
	Module: User Setting	New user is added

	-Add User	
AC-009	Module: TAT Setting -Add TAT	New TAT record is added.
	Module: TAT Setting -Edit TAT	TAT record is edited.
AC-010	Module: WIP -Add WIP	New WIP record is added
	Module: WIP -Edit WIP	Selected WIP record is edited
	Module: WIP -Delete WIP	Selected WIP record is deleted
AC-011	Module: Summary	Summary of: (i) PO by Company (ii) WIP by Product
AC-012	Module: Logout	User is logged out
AC-013	Generate Table for new product	

7 Conclusion

Real time WIP information is vital in MRO operation as for advanced monitoring, analyzing and reporting purposes. This paper had been discussed the problem of the conventional paper based WIP in the company. The main problems are the traditional way of updating the WIP that is prone to errors and the difficulty in tracking the parts due to rework and scrap. Therefore, the real time WIP tracking system had been proposed as to meet the challenges of the dynamic work flow and to overcome the shortcomings of the conventional approach. System development and implementation had been further discussed in this paper. With this proposed system, the WIP information is updated efficiently and accurately. Since, the WIP information can be accessed immediately; real time monitoring is enabled to ensure the production line performance.

References

[1] NG, T.J., Wong, M.M., Zhang, J.B. and Gan, O.P. RFID for MRO Works in Progress Tracking. *IECON 2006*. pp. 4779-4784.

2] Wang, J.H., Luo, Z.W., Wong, E.C. and Tan, C.J. RFID Assisted Object Tracking for Automating Manufacturing Assembly Lines. *ICEBE 2007*. pp.48-53.

[3] Schroeder, R.G. (1993) Operations management: decision making in the operations function. McGraw-Hill, Singapore.

[4] Nahavandi, S., Abachi, H.R. and Abdollahian, M. A Dynamic Decision Making System for Manufacturing Control. *ICSTM 2000*.

[5] Huang, G.Q., Zhang, Y.F. and Jiang, P.Y. RFID-based wireless manufacturing for real-time management of job shop WIP inventories. *Int J Adv Manuf Technol*, in press. (doi:10.1007/s00170-006-897-4)

[6] MRO is Major RFID Opportunity for Aero and Defense. Retrieved November 2nd, 2006 from http://www.rfidupdate.com/articles/index.php?id=123[7] V. Drona, S. Drona, C. Rusell, M. H. N. Tabrizi (2009). RFID based Learning Assessment System. *WSEAS TRANSACTIONS on COMPUTERS.* Issue 6, Volume 8, June 2009.

[8] Chin-Ling Chen, Yu-Yi Chen, Yu-Cheng Huang, Chen-Shen Liu, Chia-I Lin, Tzay-Farn Shih. Anti-Counterfeit Ownership Transfer Protocol for Low Cost RFID System. *WSEAS TRANSACTIONS on COMPUTERS*. Issue 8, Volume 7, August 2008.

[9] Ming-Shen Jina, Kuen Shiuh Yang, Chung-Lun Lee. Modular RFID Parking Management System based on Existed Gate System Integration. *WSEAS TRANSACTIONS on SYSTEMS*. Issue 6, Volume 7, June 2008.

[10] Ming-Shen Jian, Kuen Shiuh Yang, Chung-Lun Lee Context and Location Aware Public/Personal Information Service based on RFID System Integration *WSEAS TRANSACTIONS on SYSTEMS*. Issue 6, Volume 7, June 2008.

[11] Mehmet. RFID Advantage and disadvantage. Retrieved August 20th, 2009 from http://forum.rficdesign.com/YaBB.pl?num=1228841512.

[12] IDAutomation. RFID FAQ & Tutorial. Retrieved August 20th, 2009 from http://www.idautomation.com/rfid_faq.html#RFID_Advantages.

[13] Narayanan A., Sanjay Singh and Somasekharan M. Implementing RFID in Library: Methodologies, Advantages & Disadvantages. Retrieved August 20th, 2009 from http://docs.google.com/gview?a=v&q=cache:1AIgOZ_YB3UJ:library.igcar.gov.in/readit-

2005/conpro/lgw/s5-8.pdf+advantage+and+disadvantage+of+RFID&hl=en&gl=my.
[14] Tomáš Potkan. The Progress In RFID Technology. Retrieved August 20th, 2009 from http://ks.utc.sk/casopis/pdf/III2009/potkan.pdf.