UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT OF TRACEABILITY MODEL FOR INEXPENSIVE HIGH-VOLUME ITEMS

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By

MAHMOOD REZA KHABBAZI

Thesis Submitted to the School of graduate Studies, University Putra Malaysia, in Fulfillment of Requirements for the Degree of Master of Science

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DEDICATION

To my Mother, who her love and compassion endlessly pours on me

To my Father, who his words and support constantly encourages me

To my lovely Brothers, Mohammad, Amir Abbas,

and Majid - May his kind soul rest in peace

And to all my Friends, specially Alireza who warmly helped me in everything

Abstract of thesis presented to the senate of university Putra Malaysia in fulfillment of the requirement for the degree of Master of Science

DEVELOPMENT OF TRACEABILITY MODEL FOR INEXPENSIVE HIGH-VOLUME ITEMS

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March 2009

Chairman: Mohd. Yusof Ismail, PhD

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Having a traceability system in a company which produces goods or services is something that can help to assure the customer's or the company's security, safety, and satisfaction. Information created by this system will help to improve the quality and also to find the clues of the production problem occurrences. A database system in which storage and retrieval of information is performed is the most applicable method to meet this need and fulfill this demand.

This thesis focuses on the data modeling for traceability system in information layer of manufacturing control system that is devoted for non-expensive high volume items as final goods in all aspects production and control operations. A useful database system that could be applicable in many identical cases for lot-base traceability for material flow is developed through data modeling. The designed model improves the applicability of lot traceability with dynamic store and retrieval of the manufacturing

and quality data. The functionality of the computerized traceability information system requirement is successfully evaluated through implementing data queries.

As the result, the developed model promises to handle fundamental issues of traceability system effectively. It supports for customization and real-time control of material flow in all quality and production operation processes. Through prototype implementation of the model, recording deviations and therefore, assessing their impacts become easier. The computerized information system with better visibility and dynamic data processing handles all traceability usages and applications efficiently. Due to the case and nature of this thesis is not for a complex enterprise, it can be concluded that the model is initially applicable to environment with identical operational boundaries and complexity.

A case study in car component industry which provides the fundamental idea and key solution is presented. ERM (Entity Relationship Modeling) and pertaining diagrams (Entity Relationship Diagram) are used as modeling tool for its easy-understanding and applicability in modeling of high volume data. Microsoft Access is selected as database platform in this study due to its availability at all manufacturers especially small-to-medium size enterprises. The designed database includes main console with two options of data entry forms, and reports. Data entry is made manually and from customer order to final product inspections. Report option is designed to acquire desired traceability information such as lot relations.

The solution is limited to material flow control excluding all resources and capacity related issues in the planning functionality. The model developed for a single company environment with batch production system for Make-to-Order.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master Sains

PEMBANGUNAN MODEL KEBOLEHKESANAN UNTUK BARANG TIDAK MAHAL BERVOLUM TINGGI

Oleh

MAHMOOD REZA KHABBAZI

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Sistem kebolehkesanan di dalam sesebuah syarikat yang mengeluarkan barangan atau menyediakan perkhidmatan dapat menjamin, keselamatan, keselamatan dan kepuasan pelanggan mereka. Maklumat yang terhasil dari sistem dapat membantu meningkatkan kualiti serta dapat mencari jawapan kepada masalah pembuatan. Satu sistem pengkalan data dimana penyetoran dan pengeluaran maklumat dilakukan merupakan satu kaedah yang dapat memenuhi keperluan pelanggan ini.

Tesis ini memberi fokus kepada pemodelan data referens untuk sistim kebolehkesanan dalam lapisan maklumat dari sistem kawalan pembuatan yang dikhaskan untuk item volum tinggi yang tidak mahal sebagai barang akhir dalam semua aspek pengeluaran dan kawalan operasi. Suatu sistem pengkalan data yang dapat diaplikasikan untuk kes kes yang serupa bagi kebolehkesanan aliran bahan berasaskan lot dapat dibangunkan melalui pemodelan data. Model yang direkabentuk telah dapat meningkatkan kebolehkesanan lot melalui penyimpanan dan penyetoran data yang dinamik. Sistem kebolehkesanan maklumat berkomputer ini telah diuji dengan jayanya melalui perlaksanaan data berfangsi.

Model yang dibangunkan dijangka akan dapat menyelesaikan isu isu sistem kebolehkesanan secara efektif. Ianya akan dapat mendokong pengkhususan dan kawalan real-time barang masuk untuk semua proses berkaitan kualiti dan operasi pengeluaran. Melalui model tersebut, catitan terhadap sebarang penyimpangan dan penilaian impaknya menjadi lebih mudah. Juga melalui keupayaan penglihatan dan penyimpanan dinamik yang lebih baik kesemua kegunaan dan aplikasi dari kebolehkesanan dapat disediakan. Kajian tesis ini juga tidak direka untuk syarikat yang komplek maka oleh sebab itu model data-referens ini adalah sesuai untuk digunakan dalam persekitaran yang mempunyai operasi sempadan dan kesukaran yang sama.

Kajian kes ini telah dijalankan terhadap sebuah syarikat komponen kereta yang menjadi asas sistem untuk pmbinaan pemodelan barang barang kecil tapi murah ini. Syarikat ini juga telah menyediakan penyelesaiannya. ERM dan carta carta yang berkaitan telah digunakan sebagai alat pemodelan untuk memudehkan pemahamannya dan digunakan untuk kegunaan data volum tinggi. Microsoft Access telah dipilih sebajai platform pengkalan data kerana perisian ini mudah diperolehi oleh syarikat syarikat pengeluar terutama diperusahaan kecil dan sederhana. Rekabentuk pengkalan termasuk konsol utama dengan dua pilihan iaitu dengan pengisian data dan laporan. Pengisian data dibuat secara manual dari pesanan pelanggan sehingga pemeriksaan produk akhir. Manakala pilihan laporan direka untuk memperolehi maklumat yang dikehendaki seperti hubungan lot.

Penyelesaian adalah terhad kepada kawalan aliran barang dan tidak termasuk isu isu yang berkaitan dengan kesemua sumber dan kapasiti yang digunakan untuk perancangan. Model yang dibangunkan adalah untuk persekitaran sebuah syarikat dengan sistem pengeluaran '*make-to-order*'.

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I certify that a Thesis Examination Committee has met on 24 March 2009 to conduct the final examination of Mahmood Reza Khabbazi on his thesis entitled "Development of Traceability Model for Inexpensive High-Volume Items" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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DECLARATION

I hereby declare that this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

MAHMOOD REZA KHABBAZI

Date:

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AGV	Automatic Guide Vehicle
AM	Agile Manufacturing
BOM	Bills Of Material
CIM	Computer Integrated Manufacturing
CRM	Customer Relationship Management
EAN	European Article Number
EIS	Engineering Information System
EPC	Electronic Product Coding
ERD	Entity Relationship Diagram
ERM	Entity Relationship Modeling
ERP	Enterprise Resource Planning
ETO	Engineering To Order
FMS	Flexible Manufacturing System
GITN	Global Trade Item Numbers
GMP	Good Manufacturing Practice
HMS	Holonic Manufacturing System
IDEF1X	Integrated DEFinition for data modeling - in Computer-Aided Manufacturing (ICAM)
IMS	Intelligent Manufacturing System
ISO	International Standard Organization
JAN	Japanese Article Number
MAS	Multi-Agent Systems
MIS	Manufacturing Information System
MTO	Make To Order

MTS	Make To Stock
MRP II	Manufacturing Resource Planning
MRP	Material Requirement Planning
OPC	Operation Process Chart
QIS	Quality Information System
RFID	Radio Frequency Identification
SAP	System Application and Product in Area of Data Processing (software name and German software firm) (Systeme, Anwendungen, Produkte) in der Datenverarbeitung
SME	Small and Medium Size Enterprises
UML	Unified Modeling Language
UPC	Universal Product Code
WIP	Work In Process
LSN	Lot Serial Number
OID	Operation Identification
OSN	Order Serial Number
PID	Purchase Identification
PPID	Production Plan Identification
QFRID	Quality Fault Resolve Identification
QID	Quality Identification
QTOID	Quality Test Operation Identification
RID	Relation Identification

CHAPTER 1

INTRODUCTION

The thesis describes an empirical research study on traceability. It presents the development of a reference-data model for traceability from description of its application to evaluation of solution by using literature review, one case study, conceptual development, and prototype implementation. Emphasize of the thesis is on establishing the tracking and tracing functionality by data models so as to facilitate the development of the information system suitable for items with high amount of production with low in price and small in size.

In the first section the research description is starts with background and motivation of the study. The chapter elaborates on the problem statement. Next, the objective is to give the reader some insight into the research which follows by research method and structure of the study.

1.1 Background and Motivation

This section discusses the background of the research. The main motivation lies in the combination of information system knowledge and the manufacturing resource planning knowledge (MRP II). Normally, ERP systems manage resources as batches and lots (Van Dorp, 2002) which is recognized as an efficient approach in steady and repetitive manufacturing processes. It becomes more complex and decreases its efficiency for example when it is performed in Make-to-Order or Engineering-to-Order style. Nowadays the growing complexity of systems and products, as well as the tightening regulations addressing them, has created challenges to which existing systems have not answered completely (Rönkkö, 2006). Basic framework design principles and the structure of data stored are relatively unchallenged in recent researches on ERP systems.

MRP looks at production through material accounts, where each account represents a certain group of material units at one location (i.e. Lots or batches). The idea is to control the system by optimizing the accounts and transactions that move the material instead of looking at the products, which flow through the manufacturing process (Vollmann et al., 2004).

Tracing lots effectively is only possible by using an appropriate information system with an efficient approach of resource management. This thesis describes the subject of traceability system for small and non-expensive products with high rate of production volume in Make to Order basis production system.

Traceability is defined as ability to retain the identity of the product and its origin. Traceability is a possibility to trace the history and the usage of the product. It is the answer to the needs for many fundamental objectives like quality management, information management, risk management, logistical flow, commercial advantage, and evaluation of demand Management.

Thus, the importance of utilization and benefits of traceability are generally categorized into the advantage of ability in applications like: Recall, Product-liability-prevention, Quality-and-Process-Improvement, Proof-of-quality and proof-of-originality. Also the need of traceability underlies some underlying factors like age, origin, destination, customization, errors and variations, and illegal activities.

The decision to trace an item or not is based either on comparison of the cost and benefits of traceability or on direct external requirement, particularly the customer (Töyrylä, 1999). The decision to implement traceability for all kind of purposes and for any type of industries can be justified by: cost and benefit analysis, direct external requirement. In section 1.2, the author provides the reader some insight into tracking and tracing and into the practical problems that exist in tracking and tracing.

1.2 Problem Statement

The main purpose of any tracing system is to obtain the appropriate information with quality factors such as Accuracy, timeliness, sufficiency, easiness, reliability, and meaningfulness. Moreover, setting up a tracing system based on final product characteristics and production system type to provide useful information in applications such as Recall has always been a significant subject in manufacturing.

There are a few reference model designed for traceability in both lot-level and item-level manufacturing control logic for material flow. Caplan (1989) and Steele (1995) proposed the elements and techniques for an efficient lot-based traceability. Töyrylä (1999) studied the concept of traceability and its application in manufacturing. It categorized traceability applications base on input/output between Objects and attributes only. Van Dorp (2004) developed the reference-data model for lot-based traceability for multi environment companies in manufacturing. His model was only capable for dynamic manufacturing data processing but not for quality or purchase data. Rönkkö (2006) developed a model for item-centric (i.e. item-based) material control inspiring a case study in logistics environment which was generalized to manufacturing environment with difficulty and several mismatching. Although, he considered the operation tracing same as Van Dorp (2004) in the model, but many essential types of manufacturing data such as quality was not addressed in his model.

Even though, the ideal model to apply seems to be the item-level due to high level of information quality, but necessarily it is not the absolute way. In fact, there are three main factors that determine level of traceability information system: applicability (i.e. size, shape, price, and order size of products), importance (i.e. safety, sensitivity), and cost-effectiveness. These factors severely influence on choosing the level of traceability information system for such cases like follows.

Assume a factory in which the products are small items, customer order size is high, and production system is for Make-to-Order basis in most of times. Implementing item-level control in tracing model may seem ideal at first sight but database and other systems that store information in information layer, and automation and decision making in control layer would certainly become cumbersome and extremely costly. In addition, that would be definitely unacceptable especially when the value of items are less and cheaper than the cost estimated for implementing the item-level traceability.

Thus, the main recognized problem lies in the nature and characteristics of all kinds of non-expensive small and high volume items. In other words, Traceability of inherent information through life-cycle and possible investigation in after-sale of this type of products is considered and the fundamental problem. This important issue upholds the importance of development on design and implementation of an efficient traceability system to handle the large amount of generating data from orders, production planning and purchasing to operation processes, quality control and management.

The usage of traceability is not just restricted to applications like recall, proof-of-quality, proof-of-originality, or etc Töyrylä (1999). In fact, to find the roots of problems, remedy operation, and continuous improvement, a traceability system is one of the best tools. Thus, it is required to have a better resolution in quality data for an item or a lot/batch. This important requirement for a traceability system is not addressed by any of the designed models for traceability system (see for example Vandorp (2004) and Rönkkö (2006)).

Real-time control ability on location (i.e. operation process step), net produced amount, and quality status is essentially necessary for small and cheap items. Due to Small size, some of the items go strayed in the shop-floor. It is not beneficial to set up all production tool and equipments to produce the shortage of order amount for a cheap item. Besides, producing more than what is required to compassionate the probable shortage is not desirable due to unknowing exact amount of shortage and enormous amount of losing traceability data on pooling event for later use of inventory from warehouse. In fact, mixing the old products with new ones results to loss of efficiency and integrity of traceability system (Rönkkö 2006). Recognition on the status of high volume of small items in shop-floor is too cumbersome. Thus, the important requirement of real-time control in a traceability system for these items is absolutely necessary.

Hence, there is still a basic need to design an efficient model that could be utilized for tracing material flow or products in each level of operation inside of the organization (i.e. WIP) and/or outside the firm (i.e. after-sale and through supply chain). Upon this the generic question arises:

> "What general design for traceability system can logically be outlined to provide required information for products of small in size, high volume, and low in price?"

1.3 Objectives of the Study

To answer the aforementioned question, two objectives are outlined:

1. Designing a data model in information layer for lot-based traceability applicable for non-expensive high volume items.
2. Evaluation of functionality of the traceability requirements for the designed data model.

The first objective is limited to material flow control excluding all resources and capacity related issues in the planning functionality. The model developed for a single company environment with batch production system for Make-to-Order. The first objective addresses the issue of system design of the problem statement. The control layer is highly dependent on process layer and becomes different in every single case. So creating a generic design for this layer would be an enormous task. Also as discussed in the literature review section 2.1.3.2. and its subchapters much research and endeavor has been done for control layer in domain of multi-agent and holonic manufacturing control.

The quality operation data should not consider as static properties of the lots. In quality control and management the quality data are categorized as original data and derived data throughout product lifecycle and they express operation objects. Thus the flexibility by a dynamic store/retrieval design enables the benefits like in recall, proof-of-quality, and other quality-related applications and should be considered into the modeling.

The second objective is about the validation of the design through prototype implementation. Customization and Real-time control and investigation are checked in every angle of the designed model.

1.4 Research Methodology

Iterative and incremental design approach will be adopted as suggested by Van Dorp (2004) and Schach (2002). This is because of the combination of both is well-suited to system development where the exact specifications of the system are unknown, and is likely to create a quick and rough understanding of the design. To design a model for traceability system the steps below will be taken.

Both literature review findings and Case Study will be adopted to represent the problems and to plot the idea of this proposed Research. Literature review is divided into two main sub-chapters of: Information systems, and tracking and tracing. The case study is introducing a factory in a SME environment which is involved with the traceability problems due to its manufacturing system and products. In this case, several types of non-expensive small items with high volume customer order size are produced which requires a responsive traceability system.

Data model design is chosen as the primary method for developing the solution. Among the IDEF1x, ERM, and UML methods for data modeling, the Entity-Relationship Modeling (ERM) is chosen because of its prominent features. The notation to be used for illustration the data structuring would be Entity-Relationship Diagram (ERD). One of the most significant reasons in choosing this approach is the ability to provide easier understanding and its practicality in design. Other reason for picking this approach is the biggest applicability so far in the most researches in related field rather than more complicated ones (e.g. UML -Unified Modeling Language.

Through addition of new functionalities such as purchase, and quality information into modeling stages, the final traceability model will be achieved. The model's performance will be evaluated via applying Prototype implementation using MS Access as database platform. Through examining the requirements of the model by data queries in the prototype, the functionality of the final designed database will be evaluated.

The thesis is divided into six chapters. Chapter one as introduction comprising short preface of background and motivation of the study, problem statement, objectives, and research methodology. Literature review is discussed as chapter two including the information system, and tracking and tracing overview. Methodology is explained in chapter three. Chapter four describes the development of traceability model and evaluation of the model. Chapter five devoted to results and discussion and chapter six as conclusion. Figure 1-1 illustrates the overall research framework schematically.

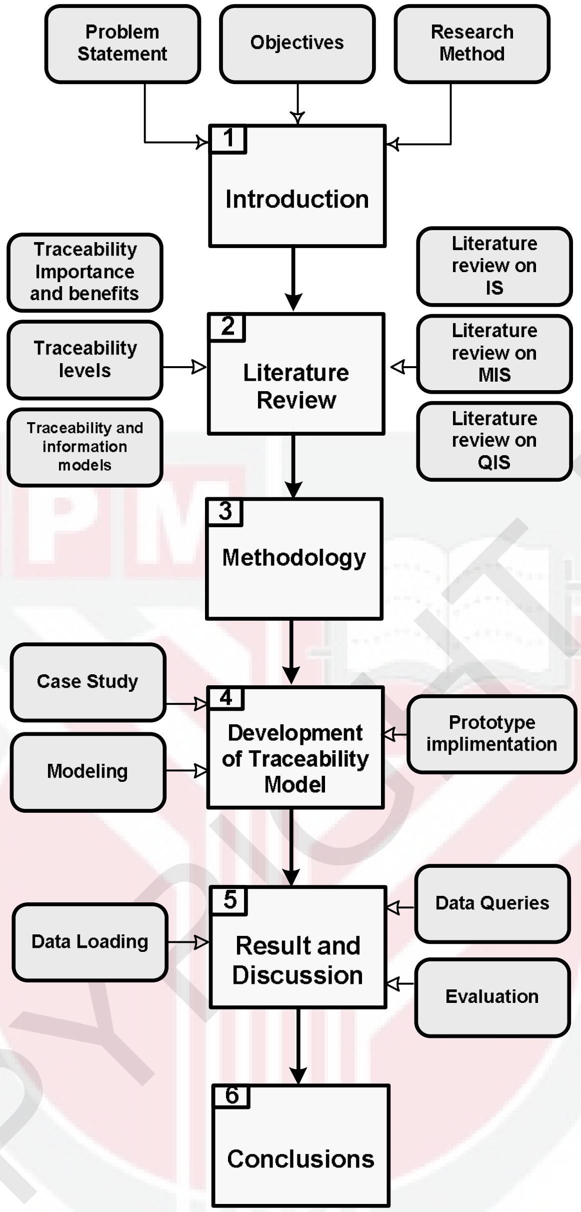

Figure 1-1: Overall Research Framework

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