

Copyright is owned by the Author of the thesis. Permission is given for a copy to be downloaded by an individual for the purpose of research and private study only. The thesis may not be reproduced elsewhere without the permission of the Author.

METHODS OF REPRESENTING THE STRUCTURE OF
COMPLEX INDUSTRIAL PRODUCTS
ON COMPUTER FILES,
TO FACILITATE PLANNING, COSTING
AND RELATED MANAGEMENT TASKS.

A thesis presented
in fulfilment of the requirements
for the degree of
Master of Technology in
Manufacturing and Industrial Technology
at
Massey University

SARA BURNS

1992

658.5
Bur

nlao

ABSTRACT

When the original concepts for the computerisation of product structures were developed in the late 1960's the available computer power was very limited. A modularisation technique was developed to address the situation in which a number of similar products were being manufactured. This technique tried to rationalise these products into family groups.

Each member of the family differed from the others due to the possession of different features or options. However there was also a high degree of commonality to give the product membership of the family. Modularisation involved the identification of the options and features providing the variability. Those parts remaining tended to be common to all members of the family and became known as the common parts. Separate Bills of Material (BOMs) were set up for each of the identified options or features. Another BOM was set up for the common parts. The simple combination of the required options and/or features BOMs with the common parts BOM specified a product. Computer storage requirements and redundancy were reduced to a minimum. The Materials Requirements Planning (MRP) system could manipulate these option and feature BOMs to over plan product variability without over planning the parts common to all members. The modularisation philosophy had wide acceptance and is the foundation of MRP training.

Modularisation, developed for MRP, is generally parts orientated. An unfortunate side effect tends to be the loss of product structure information. Most commercial software would list 6 resistors, Part No. 123, in the common parts BOM without concern as to where the resistors are fitted. This loss of product structure information can hide the fact that two products using these 6 resistors 'in common' are in fact different as they do not use the resistors in the same 6 places. Additional information must be consulted to enable the correct assembly of the 'common' portion of these products.

The electronics industry is especially affected by this situation. This industry has changed considerably since the late 1960's. Product variability can be very high. Changes and enhancements are a constant factor in products having a relatively short life span. The modularisation technique does not have a good mechanism for the situation where an option itself has options or features. This situation can exist down a number of layers of the family tree structure of an electronics product. Maintenance of these BOMs is difficult.

Where there are options within options the designers and production staff need to know the inter-relationship of parts between options to ensure accuracy, compatibility and plan assembly functions. The advent of computerised spreadsheets has made the maintenance of this type of product structure information easier. This matrix is another separate document which must be maintained and cross checked. It will inevitably differ from the BOMs periodically.

This thesis develops a product structure Relational BOM based on the matrix for the family of products. The processing power of the 1990's computer is fully utilised to derive the common parts for any or all of the selected products of the family. All product structure information is retained and the inter-relationship of parts is highly visible. The physical maintenance of the BOMs is simple. The BOM serves all purposes without the need for supplementary information. It is fully integrated into the Sales Order Entry , MRP, Costing, Engineering Design and Computer Aided Manufacturing (CAM) systems.

This technique has been proven by being the only system used in one Electronics Design and Manufacturing organisation for over 1 year without any major problems.

As described in Section 1.6 user satisfaction has been high. The response of the users to the suggestion 'lets buy an "off the shelf" package' is very negative, as it would not incorporate this BOM system. Users have expressed the opinion that EXICOM could not continue, with present staffing levels, using the traditional BOM structure.

ACKNOWLEDGMENTS

I wish to thank the management and staff of EXICOM without whose co-operation this study would not have been possible. The faith they pinned on a totally untried concept demonstrates the desperate situation which had developed. The fact that management were unable to find consultants able to suggest a better course of action is indicative of the lack of understanding within this country, and possibly further afield, of this problem. Most consultants had not thought beyond the accepted methodology as developed in the late 1960s.

One group of consultants which may have been able to assist have been of extensive assistance to me with the writing of this thesis. I refer to the staff of the Production Technology Department of Massey University. I wish to thank Harvey Barraclough for his guidance especially in the wider thinking of how this concept could be applied to other computer systems and Roger Browne for his guidance in the writing of this thesis.

I wish to thank Ned Davies, the contract programmer for EXICOM, who made this concept a reality. During previous projects Ned had given me a good grounding on how the PICK system file structures worked and generally taught me how to use the programming language. At that stage, as I was not permitted to write software code for the corporate computer, I had to rely on Ned's ability to translate my concepts into a robust useable code. He acted as a good sounding board for some of my ideas which initially sounded impossible. His teaching, combined with my own reading, was sufficient to allow me to take over all the programming tasks and maintain the system when his contract was reduced due to changes in the company financial situation.

Lastly I wish to thank my family who have lived with this study for two years. Without their continuing support and understanding this thesis would not have been possible.

TABLE OF CONTENTS

INTRODUCTION.....	1
1.1. Background	1
1.2. Information Needs	2
1.2.1. Parts Listings	2
1.2.1.1. Historical	2
1.2.1.2. Present.....	3
1.2.1.3. Future.....	3
1.2.2. Engineering Drawings.....	3
1.2.2.1. Circuit Diagrams.....	3
1.2.2.2. Printed Circuit Boards.....	4
1.2.3. Materials Nomenclature	4
1.2.4. Product Structure	5
1.2.5. Manufacturing Processes	5
1.2.6. Tooling	5
1.2.7. Jigs and Fixtures.....	5
1.2.8. Work Instructions.....	6
1.2.9. Serial Numbers	6
1.2.10. Costing.....	6
1.2.11. Inventory	6
1.3. Development of Computerised Systems.....	7
1.3.1. Requirements Planning.....	7
1.3.1.1. Independent Demand.....	7
1.3.1.2. Dependant Demand	7
1.3.1.3. Explosion Chart or Planning Matrix.....	8
1.3.1.4. Common Parts.....	9
1.3.2. Data Elements of Bills of Material.....	9
1.3.2.1. Item Master Data.....	9
1.3.2.2. Product Structure Data.....	9
1.3.3. Material Requirements Planning (MRP)	10
1.3.4. Modularisation of the BOMs.....	11
1.3.5. Computer Memory Restrictions.....	13
1.4. Simple Example to Demonstrate EXICOM Situation	14
1.4.1. Replacement of an Optional Part.....	16
1.4.2. Replacement of a Common Part.....	16
1.4.3. Affect on the Matrix BOM.....	17
1.4.4. Introduction of a New Option	17

1.5. Definition of Family	18
1.6. Suitability of Accepted Philosophy	19
2. PROBLEM DEFINITION.....	21
2.1. Description of Problem	21
2.2. Structuring the BOMs	23
2.3. Description of Products	26
2.4. Product Code Derivation	28
2.5. Sales Order Entry	28
2.6. Summary.....	28
3. TRADITIONAL METHODOLOGY.....	30
3.1. Modularisation	31
3.2. Single Master Concept	34
3.3. Multi-level BOMs	35
3.4. Phantom Assemblies	35
3.5. Mini-BOMs.....	35
3.6. Circuit References - Balloon Numbers	36
3.7. Multiple BOMs	36
4. EXISTING BOM SYSTEM AS USED BY EXICOM.....	37
4.1. Material Numbers	37
4.2. Centre File.....	39
4.3. Operations File.....	39
4.4. Mini-BOMs.....	40
4.5. Assembly Codes.....	42
5. RBOM - A RELATIONAL BILLS OF MATERIAL	43
5.1. General Data Model	44
5.2. Generic Header	46
5.3. Generic - Variants.....	47
5.4. Generic - Reference	48
5.5. Generic - Reference - Part	49
5.6. Parts or Materials	50
5.7. Generic - Reference - Part - Sequence - Variant	51
5.8. RBOM Explosion	52
5.9. Summary.....	53
6. PICK DATABASE DESCRIPTION.....	54
6.1. PICK Structure.....	54
6.1.1. File Structure	54
6.1.2. Data Storage.....	56
6.1.3. Item Storage	58

6.2. Data Addressing	59
6.3. Relational Database	60
6.4 Query Language.....	63
6.4.1. General.....	63
6.4.2. Data Dictionary	63
6.4.3. Conversions.....	64
6.4.4. Translations	64
7. PICK IMPLEMENTATION	66
7.1. PICK Record Structure for RBOM	66
7.2. Generic Header - (BOM.HEADER).....	68
7.2.1. Generic BOM's.....	68
7.2.2. Phantom C0100's.....	69
7.3. Mini-BOMs.....	70
7.4. Generic - Reference - (BOM.DETAILS).....	71
7.4.1. Generic BOMs and C0100's	71
7.4.2. Mini-BOMs	72
7.5. Attribute Properties.....	73
7.5.1. BOM.HEADER	73
7.5.1.1. Variants.....	73
7.5.1.2. Variant Status.....	76
7.5.1.2.1. Provisional Status.....	76
7.5.1.3. Last Reference Number	76
7.5.1.4. Index	77
7.5.1.5. Description	79
7.5.1.6. Accounting Group	79
7.5.1.7. Manufacturing Option.....	79
7.5.1.7.1. Manufacture in house.....	79
7.5.1.7.2. Sub-contract.....	79
7.5.1.7.3. Advance Manufacture.....	80
7.5.2. BOM.DETAILS	81
7.5.2.1. Reference.....	81
7.5.2.2. Part Numbers	81
7.5.2.3. Quantity.....	82
7.5.2.4. M00# - Centre and Operation	82
7.5.2.5. 'P' Flags.....	82
7.5.2.6. Assembly Code	82
7.5.2.7. Drawing Issue Number.....	83
7.5.2.8. Change Orders.....	83

7.5.2.9. Options.....	83
7.5.2.10. Effectivity.....	86
7.5.2.11. Current Change.....	86
7.6. Installation	87
8. FEATURES OF NEW SYSTEM	88
8.1. Navigation through RBOM.....	89
8.1.1. Recursion.....	90
8.1.2. Display Options.....	92
8.1.3. Obsolete switch.....	94
8.2. Effectivities	95
8.2.1. Hide or Unhide.....	97
8.3. BOM Explosion Mechanism.....	98
8.4. Creation of new variant.....	99
8.4.1. Option Flag Status	100
8.4.2. Provisional status.....	100
8.4.2.1. Preservation of history	100
8.5. Reference as Key	101
8.6. Change Order System	102
8.6.1. Printout of stated references.....	102
8.6.2. Too complex to be software driven	103
8.6.3. Change Order timing.....	103
8.6.4. Check print audit trail.....	103
8.6.5. Printout incorporating Change Order.....	103
8.7. Editing Changes	104
8.7.1. Close line	104
8.7.2. Copy line.....	104
8.7.3. Reopen line.....	104
8.7.4. Add or Insert a details line	105
8.7.5. Change details line	105
8.7.6. Delete details line	106
8.8. Where-Used	107
8.8.1. Effectivities.....	107
8.9. Global Change.....	107
8.10. Substitutes.....	108
8.10.1. All or nothing.....	108
8.10.2. Seek existing substitute to reuse	108
8.11. Search facilities	110

8.12. BOM Reports	111
8.12.1. Indented BOM - All parts.....	113
8.12.2. Indented BOM - Common Only.....	114
8.12.3. Indented BOM - Non-Common Only	115
8.12.4. Indented BOM - Parts for a specified M00#.....	116
8.12.5. Indented BOM - Comparison between selected variants	117
8.12.6. Indented BOM - Comparisons between a variant at different effectivities.....	118
8.12.7. Indented BOM - Exploded lower levels.....	119
8.12.8. Single Level BOM	120
8.12.8.1. Single Level - Parent BOM.....	120
8.12.8.2. Single Level - C0100 Sub-assembly or Mini- BOM	121
9. INTERACTION WITH OTHER SYSTEMS	122
9.1. Sales Order Entry	122
9.2. Forecasting.....	124
9.3. Production Groups.....	126
9.4. Material Requirements Planning	127
9.5. Allocation of Customer Sales to Forecast	130
9.6. Operations Approval.....	133
9.7. Production Planning	134
9.8. Production Release	136
9.9. Issue	139
9.10. Machine Programs.....	140
9.11. Serial Numbers	141
9.12. Boardline	142
9.13. Costing	143
10. USER REACTION	144
10.1. Environment.....	144
10.2. Breadth of Knowledge	145
10.3. Increasing Variants.....	146
10.4. In-house Software.....	146

11. PROBLEMS ENCOUNTERED	147
11.1. Problems with the design or concept.....	148
11.1.1. Concept of Effectivity Dates.....	148
11.1.1.1. Changes made after the Effectivity	149
11.1.2. Provisional BOMs getting to the Issue stage	150
11.1.3. Variant not in BOM - obsolete product.....	151
11.1.4. Changing the Manufacturing Option.....	152
11.1.5. Maintenance of obsolete variants	153
11.2. Problems with Version 1 of the software	154
11.2.1. Access Restrictions - once approved.....	154
11.2.2. Adding unconverted Mini-BOMs into products.....	155
11.2.3. Addition of a C0100- Assembly to an existing BOM	156
11.2.4. Spares utilising only one C0100 assembly	157
11.2.5. Need to know when a variant has been added.....	158
11.2.6. Too many variants for screen display	159
11.2.7. Too many variants for printout.....	161
11.2.8. Receipt of parts specified in Mini-BOMs.....	164
11.2.9. Where-Used Effectivities and Obsolete.....	166
12. FURTHER WORK.....	167
12.1. Purge BOM of obsolete or unwanted variants.....	167
13. PORTABILITY OF RBOM	169
14. CONCLUSIONS	172
15. BIBLIOGRAPHY.....	174
16. GLOSSARY.....	178

List of Figures

1.1	Explosion chart or planning matrix.....	8
1.2	Bills of Material for Products 1 and 5.....	9
1.3	Super Bill for family of products.....	12
1.4	Matrix BOM showing a simple family of beads	14
1.5	Common Parts for the bead family maintaining the product structure ..	15
1.6	Common Parts for the bead family discarding the product structure	15
1.7	The option dependant parts retaining the product structure information.....	16
2.1	Printed Circuit Board showing some component positions.....	22
2.2	Printed Circuit Board showing a Functional Block.....	23
2.3	Variants made up of Common Parts plus function block assemblies.....	24
2.4	Redistribution of the Common Parts assembly amongst each variant.....	24
2.5	Redistribution of the common and variant dependant components of Functional Block1a between Variants 1 and 6	25
2.6	Layout of modules within a frame	27
3.1	A selection of possible optional features	30
3.2	Common Parts plus Options for a generic product.....	33
3.3	Creating a sub-assembly from two similar options	34

4.1	M00# placed within an indented BOM.....	40
4.2(a)	All parts to be included in parts requirements	41
4.2(b)	No parts to be included in parts requirements.....	41
4.2(c)	Only 'P' flagged parts to be included in parts requirements - R0701-00005.....	41
5.1	Model of a Relational Bills of Material	44
5.2	Entity-Relationship Data Model	45
5.3	BOM.HEADER Table showing some possible attributes.....	46
5.4	BOM.VARIANTS Table showing some attributes.....	47
5.5	BOM.REFERENCE Table showing possible attributes	48
5.6	BOM.PARTS Table showing some attributes	49
5.7	MATERIAL Table showing some attributes	50
5.8	BOM.DETAILS Table showing some of the possible attributes.....	51
6.1	Pictorial representation of PICK file structure showing modulo and separation.....	55
6.2	Typical layout of the contents of a group showing attributes, multi-values and sub-values	57
6.3	Logical representation of an item	59
6.4	Items of the Employees file.....	61
6.5	Conversion of dates.....	64

6.6	Translation between files to obtain information for ACCESS enquiries	65
7.1	Entity-Relationship Data Model showing the two files used. The major attributes are listed against the applicable files.....	67
7.2	BOM.HEADER file showing a typical logical view for a Generic BOM based on Figure 5.1.....	68
7.3	BOM.HEADER file showing a typical logical view for a Phantom C0100 BOM.....	69
7.4	BOM.HEADER file showing a typical logical view for a MINI-BOM.....	70
7.5	BOM.DETAILS showing a typical logical view for a Generic BOM*Ref or a C0100-*Ref based on Figure 5.1. The date would normally be stored in internal format	71
7.6	BOM.DETAILS file showing typical logical view for an Mini-BOM.....	72
7.7	A possible screen display of the BOM listed in Figure 5.1 with all variants current. The variants have been sorted into <u>ZZZZZ</u> order	74
7.8	A possible screen display of the BOM listed in Figure 5.1. In this case Variant 1 has an Obsolete flag set in the MATERIAL File	74
7.9	A possible screen display of a C0100- assembly with all variants current. Description is read from the MATERIAL File.....	75
7.10	A possible screen display of a Mini-BOM. Description is read from the MATERIAL File.....	75
7.11	A possible screen display of the Index showing references read from BOM.DETAILS and descriptions read from MATERIAL	78
7.12	A possible screen display of the Index showing a new reference R3 added through the Change Order procedure.....	78

7.13	A possible screen display of the BOM for Advance Manufacture.....	80
7.14	A possible screen display of a Mini-BOM with references as listed on the drawing.....	81
7.15	Possible BOM.DETAILS display of Figures 5.1 and 7.5 showing all products and parts.....	84
7.16	Possible BOM.DETAILS display of Figures 5.1 and 7.5 showing all products but only valid parts for the effectivity date shown.....	85
7.17	Possible BOM.DETAILS display of Figures 5.1 and 7.5 showing all products and parts. An effectivity date has been included, in external format as in Figure 7.5.....	86
8.1	Navigation through RBOM.....	89
8.2	Against C0201-27266 in the BOM INDEX screen input M for Matrix display to see details of which variants use the Mini-BOM.....	90
8.3	Further explosion of the Mini-BOM is actioned by the input of an M for Matrix against the line entry.....	91
8.4	Recursive explosion of a Mini-BOM from the generic BOM. The BOM.HEADER is suppressed.....	91
8.5	BOM.DETAILS with Variants Option. The option flag is positioned below the vertical ZZZZZ of the applicable variant.....	92
8.6	BOM.DETAILS with Effectivities Option. The effectivity is shown in external format for ease of understanding. Normally this would be in internal format.....	93
8.7	BOM.DETAILS with Descriptions Option. The description within the MATERIAL file is displayed for each part. The option flag for the last displayed part (Part9) is written.....	93

8.8	Screen display of all variants including obsolete. The word Obsolete is displayed to advise the user	94
8.9	Screen display of non-obsolete variants only	94
8.10	BOM.DETAILS with Effectivities Option. The Hide switch is on and only current parts are shown	97
8.11	BOM.DETAILS with Effectivities Option. The Hide switch is off and all parts are shown	97
8.12	Printed Circuit Board showing a Functional Block. All these components may need to change although the true change is only within the functional block	99
8.13	Part9 is to be copied(+) and closed. The new part is Part7 which will have an effectivity start of today - 06.11.91	105
8.14	Part7 has replaced Part9 from 06.11.91. The effectivity close for Part9 is one day earlier.....	106
8.15	Part7 has been substituted for Part9 on the production run with an effectivity of 10.10.91. The effectivities show Part7 to be the current for variant 01123 on this date	109
8.16	Indented BOM showing parts for all levels	113
8.17	Indented BOM showing only the parts common for the selected variants for all levels.....	114
8.18	Indented BOM showing only the non-common parts for the selected variants for all levels.....	115
8.19	Indented BOM showing all parts for M00# M003-010 for all levels	116
8.20	Indented BOM showing comparison between two variants for the same effectivity. Only non-common parts are listed at all levels	117

8.21	Indented BOM showing comparison between the same variant at different stages of evolution. Only non-common parts are shown for all levels.....	118
8.22	Indented BOM showing explosion of lower levels	119
8.23	Single Level parent BOM.....	120
8.24	Single Level BOM for the C0100 sub-assembly	121
9.1	Forecasts for November and December deliveries	125
9.2	Screen display for Part 2 showing forecast requirements. The Date Reqd (Mfg GIS) gives 6 weeks from the first picking date until the first delivery for the month	128
9.3	Requirements Report showing only those parts where an insufficient quantity is in stock or on order. These quantities are for the specified month only and are not aggregated.....	129
9.4	Back/Forward Orders showing all proposed movements for Part 42....	130
9.5	Forecasts after adjustment to suit actual Customer Sales received.....	131
9.6	Back/Forward Orders now show sufficient product forecast to satisfy all known Customer Sales	132
9.7	A section of a Production Schedule Report. Daily Kanban rate of 10 per day.....	135
9.8	BOM showing Part 10 is substituted for an effectivity of 08.12.92 in place of Part 9	138
11.1	BOM.DETAILS screen display showing up to 40 variants with one spare column between each variant.....	159
11.2	BOM.DETAILS screen display showing over 40 variants without a spare column between each variant.....	160

11.3	Indented BOM showing groups of 1 allowing 40 columns	162
11.4	Indented BOM showing groups of 3 allowing 60 columns	162
11.5	Indented BOM showing groups of 5 allowing 66 columns	163