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A REASERCH OF DIMINISHING MANUFACTURING SOURCES AND MATERIAL SHORTAGE IN SUPPLY CHAIN MANAGEMENT

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ABSTRACT

Due to the fact that most business considered only product delivery to customer in their supply chain, follow-on logistics support often run short. It often occurs that the supply chain needs to be reconstructed or repaired when products are no longer manufactured. Military components or systems, in particular, will encounter the problem of Diminishing Manufacturing Source and Material Shortage (DMSMS) so that it needs supply chain management repair actions during its deployment phase. Due to DMSMS problems, the availability of parts is affected and the operation and support cost of electronic systems are increased. This study uses the cross-related attribute of concurrent engineering to collect and analyze maintenance data system of the customer's operational data. The concurrent engineering (CE) technique is integrated with DMSMS problems and thus results in increased efficiency of the production and the improvement of product quality. This paper discusses investigation architecture of DMSMS problem and an impact analysis of a fighter electronics system for the span of its product life cycle. It is hoped that this technique can provide a reference for management and decision making of managers when new products enter the market that they not only meet customer requirement, but also enhance company competitiveness.

INTRODUCTION

In defense and highly integrated industries, such as aerospace, precision machining, electronics and information technologies are often applied. The life cycle period, i.e. research, development, manufacture, assembly and operation, is very long for high-tech equipments/ systems or durable high-value products acquisitions and thus result in significant costs. To develop a general proper and effective cost-controllable methodology is a serious problem we need to face. The analysis of logistic support will help to achieve minimum cost, optimal performance, optimal design and optimal logistic support. The data base collected in the Government Industrial Data Exchange Program (GIDEP) show that in parts discontinuance notices, 84 percents are electronic parts or active parts (Tomczykowski *et al.,* 2003; Ruitenburga *et al.,* 2004). Diminishing material shortage research originated in DoD's investigation of vacuum tubes in 1973. Massive parts discontinuance causes significant defense spending and system availability since early nineties.

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The problem of diminishing manufacturing sources and material shortage (DMSMS) become of great concern ever since. The life cycle of a product includes pre-conceptual, conceptual design, design and verification/validation, full-scale development, manufacture and operation phases. The life cycle costs include research and development costs, production and construction costs, operation and support costs and phase-out costs as depicted (Xiaozhou *et al*., 2014; and Woo *et al*., 2014). The solution to DMSMS problem occurred in the product life cycle is the supply chain repair.

Concurrent Engineering

The setup of operating environment of concurrent engineering (CE) require basic software establishments of Computer-Aided Design/Analysis/Manufacture and their integration with the enterprise's modifications of SOP flow. The enterprise's modification of SOP flow is the basis of the application of concurrent engineering. In early design process, functional groups work in their own domains so that professional idea exchanges occur only in upstream and downstream processes and gaps of design philosophy often occur in the product development phase. Although there are processes of functional review for blueprint and engineering order, errors still occur in this complex and multiple-disciplinary engineering integration tasks. When problems are detected in initial manufacturing and assembly, they need functional groups to clear problems and to execute operating procedures of modifications of design and blueprints until all are correct. Problems in this category could happen and cause severe delay of the program schedule (Department of Defense, 2005). To improve the quality of the product and shorten the product development period, modification of process flow must be done, i.e. each functional group should handle its own work objectives and function. However, this is only an element view. A plan to integrate the needed information of each functional group with the information of production capability effectively will create a hierarchy view from upstream, downstream, and parallel connections. The management system will be planed according to product life cycle instead of management system of discrete functional elements so the management system will function from a overall view. Concurrent engineering is a management concept of engineering and technology but not a function of the computer system. Concurrent engineering does not introduce computer-aided design/analysis/manufacturing system, but the latter is indispensable for the former. Due to the rapid development of computers, the development of computer-aided systems is also very quick. Its system development comprises the following phases.

Blueprint Computerization Phase

In this phase mainly a three-view system using computer drawing instead of manual drawing is created. However, its points and lines are based on three dimensional coordinates.

Three Dimensional Database Phase

Parts design requires database. The database includes information of 3-D geometrical shapes and designs, such as materials, weights, surface finishes, heat treatments, construction codes. 3-D geometrical data can be used by the downstream functional groups, such as subsystems groups, manufacturing groups, and analysis groups. Design information can be used to establish management systems, such as materials, material sizes and metal parts, and therefore Bill of Materials for procuring raw materials and metal parts.

Theoretical Model and Collected Data Analysis

Theoretical Model

The value chain of average enterprise only includes considerations of product delivery to customers, but is not integrated with after-sale services, and that causes the problem of supply chain repair. This investigation tries to explore this problem throughout the life cycle. It is hoped that we can solve DMSMS problems effectively through the mechanism of concurrent engineering. We use modified Afuah's technology and market knowledge model as shown in Fig. 1 (Carter, 1999).

Flow Chart of Data Collection and Analysis

We collected customer's field data (since 1992) through on-site visits and use self-developed customer maintenance data collection and analysis system software to analyze and validate the results and benefits. The customer's data collection and analysis process is shown in Fig. 2.

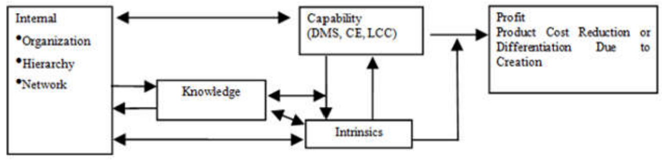

Fig. 1. Modified Afuah's model

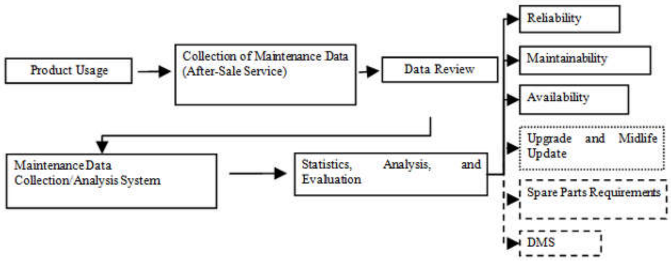

Fig. 2. Flow chart of customer data collection and analysis

Evaluation and Execution Procedures

The problems of diminishing sources of parts require systematic methodology and procedures to identify, analyze, and solve. The U. S. DoD policy of DMSMS problems is based on DoD Regulation 4140.1-R Material Management Code Chapter 1.4 DMSMS policy and procedure execution (Afuah *et al.,* 2003). His regulation requires that defense weapon acquisition and post-production support to execute DMSMS tasks to ensure DMSMS problems can be timely and adequately resolved in various phases of the weapon acquisition life cycle. The DMSMS units of U. S. services have established weapon acquisition procurement policy and DMSMS handbooks to facilitate this tasks, such as Army Material Command's (AMC) AMC- P 5-23 Management DMSMS (US, 2003) Air Force Material Command's (AFMC) DMSMS Case Resolution Guide (US, 1999) Naval Seal System Command's (NAVSEA) DMSMS Case Resolution Procedures Guide (US, 2001).

The theoretical basis and methodology of U. S. and European Union to solve DMSMS problems are alike. Their models can be classified into two categories:

Reactive – Solve out-of-production problems when equipment systems face DMSMS problems in life cycle phases.

Proactive – Introduce concepts of risk management and plan how to avoid the occurrences of out-of-production before they happen. Even they do happen, they can be quickly responded through corresponding organization and operating procedures. The operating procedures of resolving DMSMS problems for either reactive model or proactive model are consistent. The differences lie on whether they are early plan or execution after occurrences. The process to solve DMSMS problems can be divided into four steps as depicted in Fig. 3. They are evaluation of DMSMS problems, recognition of DMSMS problems, execution of DMSMS solution alternatives investigation, and execution of resolution and control (US, 1999).

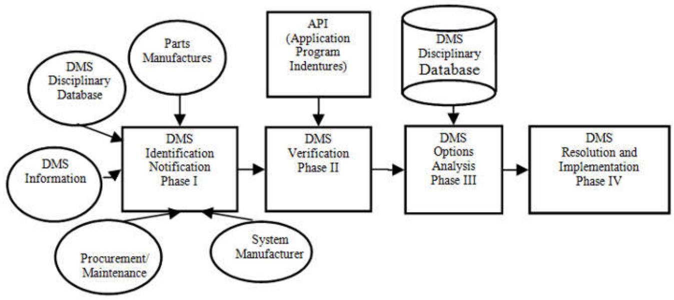

Fig. 3. Processes to solve DMSMS problems

Theoretically overall consideration of all solution alternatives is required during tradeoff studies. However, the execution priorities are the first to be considered due to the time criticality and manpower costs consideration, the evaluation of solution alternatives follows. According to the 1999th edition of Defense Micro Electronics Activity's (DMEA) cost evaluation documents, the non-recurring cost (NRC) and recurring cost of solution alternatives (see Table 1 and Table 2) can be referred to for planning execution priorities (Martin, 1997 and Sovacool, 2014).

Table 1. The Non-Recurrent Cost Factors of Dmsms Solution Alternatives

Resolution	Low	Average	High
Existing Stock	$0	$0	$0
Reclamation	$629	$1,884	$3,249
Alternate	$2,750	$6,384	$16,500
Substitute	$5,000	$18,111	$50,276
Aftermarket	$15,390	$47,360	$114,882
Emulation	$17,000	$68,012	$150,000
Redesign-Minor	$22,400	$111,034	$250,000
Redesign-Major	$200,000	$410,152	$770,000
Life of Type Buy	—	—	—

Table 2. The recurrent cost factor ratios of DMSMS solution alternatives

Resolution	Low	Average	High
Existing Stock	1.0	1.0	1.0
Reclamation	Not Available	Not Available	Not Available
Alternate	1.0	2.5	4.0
Substitute	1.6	5.8	10.0
Aftermarket	5.0	7.5	10.0
Emulation	10.0	20.0	30.0
Redesign	1,000.0	5,000.0	10,000.0
Life of Type Buy	Not Applicable	Not Applicable	Not Applicable

Case Investigation

This investigation uses self-developed customer's maintenance data and analysis system of an indigenous fighter, through on-site investigation to collect customer's data (including domestic long life cycle military products, critical avionics equipments and optimal effectiveness evaluation of solution measures) and analyze the influences of the DMSMS measures and validate their effectiveness. This investigation validates the results of DMSMS measures through sampled parts among 28 vital avionics equipments. The sampled results are shown in Table 3. There are 6,124 items in the total sampled parts, in which there are 1,283 parts with DMSMS problems, which amounts to approximately 21 percents. The solution measures are 96 replacement test (RT) items, 567 direct replacement (R) items, 123 alternative items and 375 Life-of-Type Buy (LTB) items. More accurate spare quantities are sought according to all referable data of the parts failure analysis and served as a basis to issue the procurement quantities of the LTB items. The failure rate data sources includes: in-service consumable parts application record, characteristics of LTB parts and operating environment. The number of failures was traced through reliability system calculation and main failure record of the engineering orders. Though as one of the solution alternatives of the DMSMS problems, LTB is not applicable to cost factor analysis.

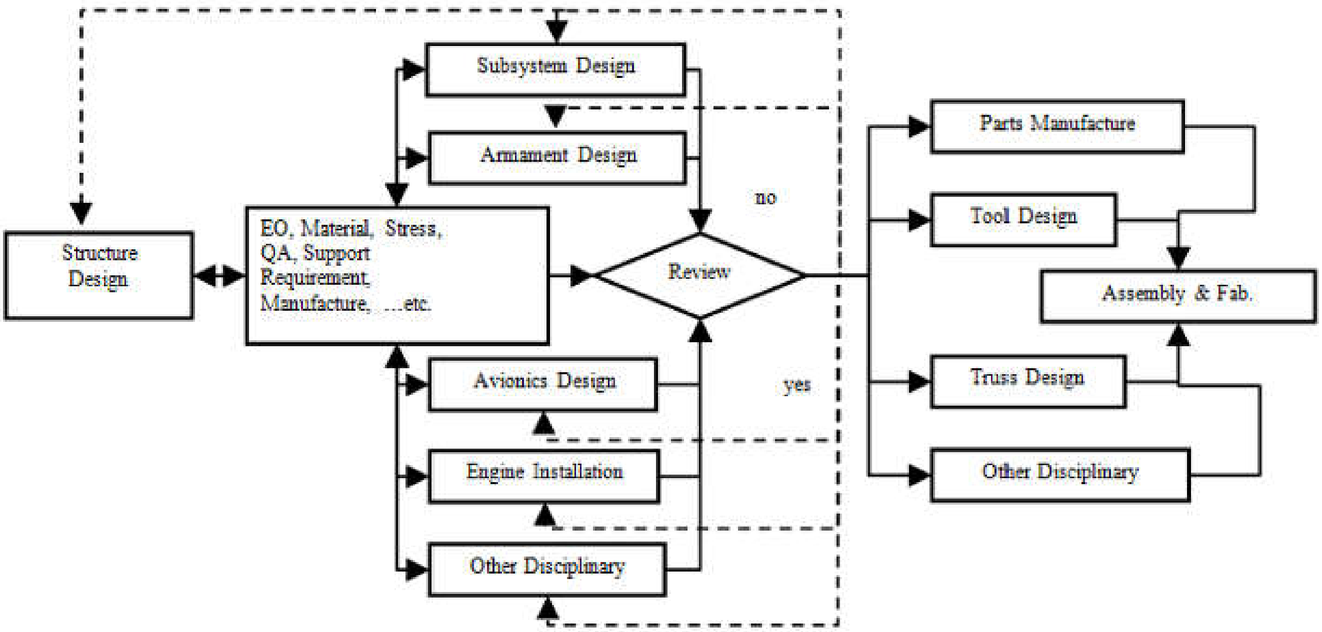

Fig. 4. Design opperations process

Table 3. The sampled results of the DMSMS parts of the avionics equipments

Item	No. of Sampled Parts	No. of out-of-production parts	LTB	DMSMS solution Alternatives	Replacements to be validated	Direct replaceable Replacements	Replacements	Stock with sufficient Support	DMSMS repair cost (NT)	Redesign-MinorCost (NT)
A	236	16	1	15	4	5	0	6	362,603	1,665,510
B	125	19	2	17	5	6	0	6	448,726	1,887,578
C	154	23	0	23	3	10	0	10	385,146	2,553782
D	79	15	2	13	0	10	3	0	200,262	1,443,442
E	379	124	48	76	11	60	5	0	1,866,712	8,438,584
F	671	321	59	262	2	162	98	0	3,695,638	29,090,908
G	27	10	0	10	0	10	0	0	181,110	1,110,340
H	46	12	6	6	0	6	0	0	108,666	666,204
I	386	147	72	75	11	64	0	0	1,907,236	8,327,550
J	266	19	11	8	4	4	0	0	344,492	888,272
K	1,295	123	32	91	8	52	9	22	1,543,324	10,104,094
L	412	79	24	55	5	38	0	12	1,028278	6,106,870
M	161	29	5	24	0	17	0	7	307,887	2,664,816
N	86	19	0	19	1	8	0	10	212,900	2,109,646
O	21	9	7	2	0	2	0	0	36,222	222,068
P	116	28	20	8	1	6	1	0	183,062	888,272
Q	68	16	12	4	0	2	0	2	36,222	444,136
S	129	23	8	15	0	15	0		271,665	1,665,510
T	128	13	5	8	0	2	0	6	36,222	888,272
U	123	19	0	19	2	7	0	10	299,023	2,109,646
V	294	59	31	28	1	20	0	7	430,232	3,108,952
W	23	2	0	2	0	0	0	2	0	222,068
X	24	3	2	1	0	0	1	0	6,384	111,034
Y	101	39	3	36	14	17	1	4	1,266439	3,997,224
Z	247	74	6	68	21	26	3	18	1,918,290	7,550,312
AA	144	14	2	12	0	10	2	0	193,878	1,332,408
AB	338	25	17	8	3	5	0	0	294,591	888,272
AC	45	3	0	3	0	3	0	0	54,333	333,102
Sum	6,124	1,283	375	908	96	567	123	122	17,619,003	100,818,872
Averagre	219	46	13.4	32	3.4	20	4.4	4.4	629,250	3,600,674

Table 4. Analysis data of average costs

Cost Items	Average	t	P
Average DMSMS repair Cost	629,250	-3.188	0.004**
Average Minor Redesign Cost	3,600,674		

**P<0.01

Instead 908 items of RT, R, replacement parts, and stock parts supportable to maintenance are analyzed. The concurrent engineering technologies are pursued to construct information management system in order to reduce DMSMS problems. This investigation compares average repair cost and the average cost (TABLE IV) of minor redesigns of 908 DMSMS repair alternatives. From TABLE III, the average DMSMS repair cost of the listed equipments is 629,250, and the average minor redesign costs is 3,600,674 with t-test parameter equal to -3.188 and probability value P equal to 0.004, i.e. the average DMSMS repair cost is significantly lower than average minor redesign cost as shown in TABLE IV.

Conclusion and Recommendation

From the result of on-site verification, we found that DMSMS repair alternatives can reduce significant cost compared with minor redesign alternatives. In cases where there are no alternatives other than the above two, the industry should take a serious look at supply chain repair problems due to DMSMS. This investigation was carried on along the system development process, using the four procedures of solution of DMSMS problems summarized from the references. Through case studies, it is validated that the DMSMS problems of the total system has caused serious effects to the execution of the system availability and mission readiness, and this will gradually deteriorate with respect to the increase of operation time. To counter the serious situation of the DMSMS problems, this investigation explores the construction of a concurrent engineering operation system composed of a team of various disciplinary groups and engaged in operation digitization and operation process reduction to create a seamless value chain and to integrate to establish a high-efficiency, high-quality, and low-cost system in order to develop specification- conformed products. The information technology operation system helps data collection, analysis and storage, increase of stock visibility and therefore reducing storage cost, shortening the planning period of the supply chain, collecting sufficient supplier information, strengthening concurrent operation, proceeding prediction and improving DMSMS crisis handling and management. Currently concurrent engineering aims at integrated development work primarily of design, analysis and manufacturing. It will integrate disciplines such as product marketing, logistics support, etc. so as to shorten product development time, perfecting production database, and solving DMSMS problems earlier. The great progress in internet and information technology, enables supply chain elements such as name-brand business, designers, manufacturers, suppliers, …etc. to co-participate product development so that designer at various locations can proceed design modification through the internet concurrently, which enhance the effectiveness of the concurrent engineering. The data manipulation management is an extension of the concurrent engineering. It is necessary to evaluate the construction of integrated database, product information management, file transfer standards, and logistic support technologies during introducing informational manipulation management system. When facing DMSMS problems, the industry should use the concurrent engineering operation environment and include this problem into consideration at the initial stage of the design process so that it will provide the most updated information inquiry and application through the digitized net architecture. This will have positive effects for execution technology development work and reduction of supply chain repair problems. Although the DMSMS problems provided by this investigation emphasized in large-scale weapon development, the industry will face DMSMS problems in various nodes in the realistic supply chain, such as the test and evaluation, logistic support software, tools, and specifications of the equipment system. Furthermore, the study suggests that the method should compare and analyze the experimental results with other methods. Taiwan is in budding stage for the study of DMSMS problems and that is why we propose the emphasis and solution measures. When the industry promotes new products, the decision variables requirements of the upstream and downstream can be consistent through mechanism of the concurrent engineering. This can provide the managers the references for decision to satisfy the customers' requirements and enhance enterprise competitiveness.

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