“An Investigation of MRP Benefit - Determinant Relationships : ACE Model”

An Investigation of MRP Benefit-Determinant Relationships: ACE Model

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Abstract

This paper is aiming to explore and examine the MRP (MRPI & MRPII) benefit-determinant relationships using the Alternating Conditional Expectation (ACE) technique within Egyptian manufacturing firms. To do that, the research is intended to test empirically the key hypothesis that the uncertainty, organisational, implementational, technological, and human variables do not correlate with the benefits obtained from MRP implementation in a linear manner. This is done by constructing a series of mathematical models for both MRP benefits measures (tangible and subjective benefits) using ACE technique as an advanced statistical modelling technique. The data analyzed in this paper were collected by a mail questionnaire to Egyptian manufacturing firms. The findings of this paper indicate that data accuracy has a positive effect on the successful implementation of MRP systems. And also, our findings indicate that as capacity uncertainty increases delivery lead time and the number of expediters increase in order to meet due dates. Moreover, our findings indicate that a company size has a positive impact on operational efficiency. Managerial implications and avenues for further research are recommended.

Key words: Uncertainty, technological, MRP Benefits, ACE, Manufacturing, Egypt.

Introduction

It has often been said that the strength of any one country resides in the strength of its industrial sector. In this respect, Egypt of the 2000 has multiplied its strength a tenth fold, exceptionally that it is also endowed with the resources and the physical means. Major strides have been taken to revamp conditions for market entry, operations and exit of businesses, by rebuilding and consolidating the infrastructure of the Egyptian industrial sector to make the Egyptian economy one of the most open and internationally integrated markets in the region. However, Egypt like most Less Developed Countries (LDCs) strives to diagnose and find solutions for the severe problems that obstruct the growth and development of its industrial sector such as: high scrap, loosing market share, high levels of inventory, poor quality in products and labor, long lead times and the existence of many sources of waste in production processes (Salaheldin & Francis, 1998; and Salaheldin, 2004). A review of the literature reveals that production managers in manufacturing companies have seen the implementation[1] of MRP as a panacea, which will cure the previous mentioned ills. Therefore, there is a lot of interest in MRP implementation among manufacturers in the Egyptian industrial sector.

Based on the researcher's observations[2], decision makers and production managers in Egyptian manufacturing firms think that the implementation of MRP would create competition and efficiency, which would lead to a better quality of life for customers at lower costs. This may also help to increase Egypt's share in the domestic market by replacing the demand for imported goods, as well as increasing Egypt's competitiveness and share in the export market. Therefore, they perceive that MRP systems need to be implemented in Egyptian manufacturing firms on a large scale.

However, authors such as Sum and Yang (1993), Sum *et al.* (1995), Salaheldin & Francis (1998), Braglia and Petroni (1999), Petroni & Rizzi (2001), and Petroni (2002), reported in their studies that there is a lack of empirical studies concerning the MRP benefit-determinant relationships in the Western manufacturing firms or in the newly industrialized countries or in Less De-

[1] The term "implementation" is used as a broad term to include pre-implementation, implementation, and post- implementation stages as in Duchessi et al. (1988); Sum and Yang (1993) and Sum et al. (1995).

[2] Interviews have been conducted with 8 general managers and 13 production managers in Egyptian manufacturing firms.

veloped Countries (LDCs) in general, and in Egypt in particular. Because of that the researcher has found it feasible to conduct this study.

Importance of the Study

This study will add to the Operations Management literature additional empirical findings in the area of MRP implementation in LDCs and its expected influence on manufacturers. The findings of this study could offer a useful potential orientation of the critical factors affecting the benefits obtained from MRP implementation to both decision makers and manufacturers who are concerned with the issue under investigation. Furthermore, as the second MRP study to use the advanced ACE technique, our ACE models cover several interesting insights into the relationships between benefits obtained from MRP implementation and determinant variables beyond these from the first study conducted by Sum *et al.* (1995).

Study Objectives

In the light of the importance of the study, there were three objectives of the current study. These were:

1. To discern the benefits obtained from MRP implementation based on the viewpoint of Egyptian manufacturing firms.
2. To identify the critical factors affecting MRP implementation.
3. To explore and examine the MRP benefit-determinant relationships.

Related Research

An extensive review of the literature reveals that MRP benefits have been measured in three ways as follows: Firstly, studies such as Anderson and Schroeder (1984); Anderson *et al.* (1982); Laforge and Sturr (1986); Cerveny & Scott (1989); Petroni and Rizzi (2001); Caridi & Cigolini (2002) and Aghazadeh (2003) have measured MRP benefits by actual use or improved performance measures. These are increasing inventory turnover, better delivery lead time, increasing percent of time meeting delivery promises, reducing percent of order requiring "splits" because of unavailable material, and reducing number of expediters. However, there is a difficulty in obtaining measures of actual use (White *et al*., 1982), because, often, companies cannot keep track of the performance measures over time (Sum *et al*., 1995). Secondly, due to the difficulties in obtaining improved performance measures several studies have decided to measure MRP benefits using user satisfaction only as in Duchessi *et al*. (1988); Sum and Yang (1993); Sum *et al*. (1995) and Caridi & Cigolini (2002). They have measured MRP benefits by attitudes, intentions or behavior of users (intangible benefits). These are improved competitive position, increased throughput, improved product quality, improved productivity, increased information on which to base decisions, better ability to meet volume/product change, better production scheduling, reduced safety stock, better cost estimation, improved co-ordination with marketing and finance, improved ability of job performance, reduced informal systems, increased Bill of Materials (BOM)/Inventory/Master Production Schedule (MPS) accuracy, and improved morale in production. Thirdly, studies such as Schroeder *et al.* (1981) and White *et al*. (1982) have measured benefits by both improved performance and subjective benefits.

On the other hand, several researchers and practitioners indicated that there are five groups of factors affecting the successful implementation of MRP systems. First, MRP implementation is affected by the degree of uncertainty and which may include serious variables such as: product characteristics diversity, amount of aggregate product demand, machine downtime, the standard of raw material (quality), behaviour of people within the factory, reliability of plant within the factory walls, capacity constraints (Puttick, 1987; Per-lind, 1991; Gerwin & Kolodny, 1993; Dilworth, 1993). Second, as pointed out by several writers such as: Anderson et al. (1982); Duchessi et al. (1988); Burns *et al.* (1991); Lee (1993); Sum *et al.* (1995); Koh *et al.* (2000); Wermus (2001) and Samaranayake *et al*. (2002) the organizational factors such as: company age, company size, type of products, type of manufacturing, layout, company complexity, organisational arrangements, organisational willingness can not be only seen as determinants of MRP implementation but also as determinants of MRP benefits. Third, it is generally believed that MRP implementation is influenced by several implementational factors such as: years in implementation, implementation strategy, degree of data accuracy, initiator of MRP effort, software/hardware vendors support and implementation problems (White, 1980; Wight, 1989; Badiru & Schlegel, 1994; Sum & Yang, 1993; Ang et al., 1995; Sum et al., 1995; Wong & Kleiner, 2001; Aghazadeh, 2003). Fourth, as put forth in numerous studies such as: Duchessi *et al*. (1988); Vollmann *et al.* (1992); Carrie & Macintosh (1993); Sum & Yang, (1993); Browne *et al.* (1996); Chung & Snyder (2000) and Keung *et al.* (2001) several technological factors (degree of integration among MRP modules, source of system, system cost, additional investment over next 3 years, user class and MRP system features) are affecting the implementation of MRP systems. Finally, as pointed out by several writers such as White *et al.* (1982); Wight (1984); Callarman & Heyl (1986); Burns *et al.* (1991); Turnipseed (1992); Sum *et al.* (1995); Ip (1998) and Chan *et al.* (1999), the problems with MRP implementation relate to people and are not technical in nature.

Moreover, Sum *et al*. (1995) concluded in their study about an analysis of Material Requirements Planning (MRP) benefits using Alternating Conditional Expectation (ACE) Model in Singapore manufacturing firms that the determinant variables such as execution data accuracy, degree of integration, planning data accuracy, technical problems, company size and people support problems do not necessarily correlate with MRP implementation benefits in a linear manner. For instance, when data accuracy deteriorates to a threshold level such that MRP users refuse to follow the recommendations produced by the system anymore, a further decrease in accuracy may not produce the same marginal or proportionate impact on benefits as before the threshold level was reached.

In sum, a review of the literature and previous empirical studies reveals that there are two gaps that need to be empirically investigated. They are:

1. No previous empirical study has tried to investigate MRP implementation in less developed countries such as Egypt.
2. Only one study has been conducted to explore the relationships between MRP benefits and their determinants (Sum *et al*., 1995).

Therefore, the current study aims to fill empirically the previous mentioned gaps. To do that, a suggest model framework of determinant variables of MRP implementation benefits is depicted below.

Table 1

The framework of determinant variables of MRP implementation benefits

Determinant Variables	Type*	MRP Implementation Benefits	Type*
Uncertainty Determinants		*Tangible Benefits*	
Product characteristics diversity	O	Inventory turnover	N
Amount of aggregate product demand	O	Delivery lead time (days)	N
Machine downtime	O	Percent of time meeting delivery promises (%)	N
The standard of raw material (quality)	O	Percent of orders requiring "splits" because of unavailable material (%)	N
Behaviour of people within the factory	O	Number of expediters (number of people)	N
Reliability of plant within the factory walls	O	*Subjective Benefits*	
Capacity constraints	O	Improved competitive position	O
Organisational Determinants		Reduced inventory costs	O
Company age	O	Increased throughput	O
Company size	O	Improved product quality	O
Type of products	C	Improved productivity	O
Type of Manufacturing	C	Better ability to meet volume/ product change	O

Table 1 (continuous)

Determinant Variables	Type*	MRP Implementation Benefits	Type*
Layout	C	Better production scheduling	O
Company complexity	O	Reduced safety stocks	O
Organisational arrangements	C	Better cost estimation	O
Organisational willingness	C	Improved co-ordination with marketing and finance	O
Implementational Determinants		Improved your ability to perform in your job	O
Years in implementation	O	Reduced informal systems for materials management/ inventory/ production control	O
Implementation strategy	C	Increased BOM/inventory/MPS accuracy	O
Degree of data accuracy	O	Increased information on which to base decisions since MRP has been implemented	O
Initiator of MRP effort	C		
Software/hardware vendors support	O		
Implementation problems	O		
Technological Determinants			
Degree of integration among MRP modules	D		
Source of system	C		
System cost	O		
Additional investment over next 3 years	O		
User class	C		
MRP system features	C		
Human Determinants			
The previous experience with the automated information systems	O		
User involvement	C		
Degree of utilising the outputs of MRP	C		
Education and formal training	C		
User support	C		

***O** refers to ordinal variable**, C** refers to categorical variable, **D** refers to discrete variable, **N** refers to numerical variable.

Hypothesis

This research is empirical and this characteristic stems from its task that is the careful and systematic investigation of the MRP benefit-determinant relationships within manufacturing firms in Egypt. Therefore, it is worthwhile working on the following hypothesis: "The uncertainty, organisational, implementational, technological, and human variables do not correlate with the benefits obtained from MRP implementation in a linear manner".

Study Methodology

The Sample

The mail survey, sent to approximately 200 ex-public (holding) manufacturing firms in Egypt, focused on (1) uncertainty determinants, (2) organizational determinants, (3) implementational determinants, (4) technological determinants, (5) human determinants, and (6) MRP benefits. Firms of the sample were randomly selected from a list of all manufacturers in the Egyptian ex-public industrial sector[1]. The target respondent in each company was the production manager or materials manager. Care was taken to include all MRP users in the sample. Usable responses of 52 were obtained resulting in a response rate of 26%. This rate was found good compared to similar studies reported in the literature (Sum and Yang, 1993, Sum *et al.* 1995).

The construction of the Questionnaire

The mail survey ***Questionnaire*** was constructed based on five successful studies previously conducted in related fields of study i.e. Schroeder *et al*. (1981), Duchessi *et al.* (1986;1989), Sum & Yang., (1993), and Sum *et al.* (1995). The modifications made to these studies were determined by the researcher's own knowledge of conditions of the Egyptian industrial sector situation and the theoretical issues discussed previously. Moreover, a pilot testing questionnaire was produced and pre-tested by academics, consultants and a small number of companies to validate the questionnaire.

Measurements

Procedures for testing Hypothesis:

1. Results of the Principal Components

The Varimax rotation technique was employed to magnify the factor loadings by maximising the variance – i.e. a measure of dispersion of a variable (Hair *et al*., (1992); or to minimise the number of variables which have a high loading on a factor, and to facilitate the interpretation of the identified factors (Hutcheson, 1997). The rotated factor matrix provides a much clearer interpretation of the results as can be seen in Tables 2 and 3 consecutively, for both the subjective benefit measures and the determinant variables.

Table 2

Subjective benefit measures factor loadings

Communality[2]	**Factors**[3]					
MRP Success Measures	1	2	3	4	5	
Factor 1: Operational Efficiency						
Increased throughput	.75					.60
Improved product quality	.67					.49
Factor 2: Co-ordination						
Better cost estimation		.70				.58
Improved co-ordination with marketing and finance		.78				.70
Factor 3: Manufacturing Planning & Control						
Better production scheduling			.70			.60
Reduced safety stocks			.68			.74
Factor 4: Formal System						
Reduced informal systems for materials management/ inventory/ production control				.74		.69
Increased BOM/inventory/MPS accuracy				.65		.58
Factor 5: Inventory Costs						
Reduced inventory costs					.79	.70

[1] Firms were identified from two sources: the General Organization for Industrialization (GOFI) and the Egyptian Industrial Chambers.

[2] Communalities mean estimates of the variance in each variable.

[3] The values underneath each factor are correlation coefficients between the factor and the variables.

Table 3

Determinant variables factor loadings

Communality	**Factors**								
Determinant Variables	1	2	3	4	5	6	7	8	
Factor 1: The Required Products									
Product characteristics diversity	.72								.64
Amount of aggregate product demand	.73								.62
The standard of raw material	.71								.53
Factor 2: Capacity									
Machine downtime		.65							.56
Capacity constraints		.80							.68
Factor 3: Reliability									
Behaviour of people within the factory			.70						.57
Reliability of plant within the factory			.74						.68
Factor 4: Technical									
Lack of suitability of hardware				.82					.72
Lack of suitability of software				.63					.53
Poor training/education on MRP				.77					.73
Factor 5: Management Support									
A lack of support from top management					.75				.73
Lack of support from production					.78				.68
Lack of support from marketing					.63				.65
Factor 6: MRP Expertise									
Lack of communication						.73			.60
Lack of information technology expertise						.75			.77
Factor 7: People Support									
Lack of support from supervisor/foreman							.76		.69
Lack of company expertise in MRP							.66		.67
Factor 8: Active Vendor Involvement									
Lack of involvement from vendor								.77	.71
	9	10	11	12	13	14	15	16	
Factor 9: Size									
Sales	.62								.52
Number of P&IC employees	.85								.81
Number of items per product	.69								.63
Factor 10: Stage of Development									
User class[1]		.65							.54
Degree of integration		.70							.57
Factor 11: Experience									
Previous experience with automated information systems			.84						.73
Factor 12: BOM Level									
Number of BOM levels				.75					.63
Factor 13: Company Maturity									
Years in operation					.75				.61

[1] For analytical purposes user class was entered to the analysis as an ordinal variable as in Duchessi et al. (1989) and Sum et al. (1995).

Table 3 (continuous)

Factor 14: Vendor Support Availability									
We expected more extensive vendor support						.76			.68
We experienced a vendor software support discontinuance problem						.73			.63
Factor 15: Active Vendor proficiency									
Vendor instructions interpret their software product							.77		.74
Vendor personnel efficiently resolved software problems							.90		.84
Factor 16: Vendor Experience									
The vendor provided conversion of our data into the new system								.93	.88
	17	18	19	20					
Factor 17: Supply Planning Data									
Capacity data	.79								.64
Vendor lead times	.76								.61
Production lead times	.63								.50
Factor 18: Demand Planning Data									
Bill of material records		.69							.58
Inventory records		.68							.76
Market forecasts		.75							.77
Factor 19: Schedule Execution Data									
Master production schedule			.87						.79
Routing/Work centre data			.63						.56
Factor 20: Operating Execution Data									
Shop floor control data				.84					.74

From Tables 2 and 3 we can notice that five out of fourteen subjective benefits measures are extracted. In addition, 20 out of 40 uncertainty, organisational, implementational, technological and human determinant variables are extracted. In turn, regression models will be developed for each benefit separately using ACE technique as it will be discussed in the next section.

2. Testing hypothesis using ACE technique

By formulating the foregoing hypothesis, the significance of the relationships can be tested with the ACE regression model as in Sum *et al*. (1995), who used this technique to analyse the MRP benefit-determinant relationships on 52 MRP users in Singapore.

As pointed out by several writers such as Brillinger and Preisler (1984); Pregibon and Vardi (1985), and Sum *et al*. (1995) Alternating Conditional Expectation (ACE) estimation can be defined as an automatic tool for finding transformations from non-linear relationships into linear ones of both the response (dependent variables) and the predictors (independent variables) that maximises the multiple correlation, R^2, to achieve increased linear associations between Y (dependent) and set X_1 ......, X_n (independent). Furthermore, the ACE model has a much better model fit compared to models produced by standard techniques such as Ordinary Least Squares and Discriminate Analysis because it is concerned with enhancing the model fit to the data rather than satisfying the model assumptions.

2.1. To decide whether transformation is necessary

One of the common methods used for determining whether a transformation necessary or not is Skewness. If the original data is non-normally distributed and the variance of error is non-constant, the linear model will be distorted and the analysis will be degraded. The Skewness method can be used to determine which data can depart from normality. It refers to the degree to which a distribution is not symmetric and which may lead to misleading results (Ratkowsky, 1983). If the ratio of the skewness to the standard error of the skew is less than -2 or greater than

+2, the data can be considered to be significantly skewed and they are candidate to be transformed and vice versa. Equation 1 shows the significance of Skewness:

$$\text{Significantly Skewed Data} = \frac{Skewness}{s.e.skew} = \geq \pm 2, \quad (1)$$

where *s.e* (standard error) denotes the square root of the variance of a sample i.e. the mean square deviation of the values of a sample from their own mean.

Table 4

Statistics to depict the significance of Skewness

Variables	Skewness	S.E. Skew	The significance of Skewed Data
Vendor experience	1.24	.33	3.76
Co-ordination	-.60	.33	-1.82
Active vendor proficiency	2.94	.33	8.91
Inventory costs	-.58	.33	-1.76
Vendor support availability	1.45	.33	4.39
Organisational willingness	.13	.33	.39
Manufacturing P&C	-.73	.33	-2.21
Supply planning data	.68	.33	2.06
Demand planning data	.59	.33	1.79
Company size	.82	.33	2.48
Levels in BOM	.31	.33	.94
Company maturity	-2.60	.33	-7.88
Stage of development	.19	.33	.58
Formal system	.04	.33	.12
Technical problems	-1.08	.33	-3.27
Schedule execution data	.11	.33	.33
Uncertain capacity	.87	.33	2.64
Uncertain required products	.10	.33	.30
Management support problems	-1.44	.33	-4.36
Active vendor involvement	.02	.33	.06
Layout	.28	.33	.85
Uncertain reliability	.35	.33	1.06
People support problems	.74	.33	2.24
Operational efficiency	.28	.33	.85
MRP expertise problem	.25	.33	.76
Experience with automated Systems	-.25	.33	-.76
Operating execution data	1.83	.33	5.55
Organisational arrangements	.96	.33	2.91
Initiator of MRP effort	2.86	.33	8.67
Implementation strategy	.91	.33	2.76
Meeting delivery promises	.30	.33	.91
Marketing strategy	.08	.33	.24
The number of expediters	-84.	.33	-2.43
The percent of split orders	-.14	.33	-.42
Source of system	.25	.33	.76
Inventory turnover	-.33	.33	-1.00
Delivery lead times	.25	.33	.76
Utilising outputs	1.33	.33	4.03
User involvement	.11	.33	.33
Manufacturing process	1.25	.33	3.79
Years in implementation	.13	.33	.39
MRP system features	.91	.33	2.67
User Support	.30	.33	.91
Education and Training	.25	.33	.76

A positive value indicates a longer right tail to the distribution and a negative value indicates a left tail (Hutcheson, 1997). Table 4 depicts the skewness statistics calculated for 44 variables represent MRP benefits and determinant variables (10:34).

The results in the last column in Table 4 indicate that 19 out of 44 variables are significantly skewed and are candidates for transformation to reduce the Skewness. Therefore, we conclude that the data of some of the variables under investigation can be described in a linear manner, and the others have the major problem (non-normality), so, transformation is necessary to approximate the data to the normal distribution, to achieve linearity related to another variable and to stabilise the variance using ACE technique as in Sum *et al*. (1995).

As a consequence, the relationships between benefits and the determinant variables can be mathematically described in a non-linear form (the parameter β_1 does not enter the model linearly). So, a regression model is non-linear as shown in Equation 2 below:

$$B = \alpha + e^{\beta 1\, D} + \varepsilon, \quad (2)$$

where B is the value of benefits (dependent variables), D is the value of determinant variables (independent variables), α is the value of B when explanatory variable (D) = 0. ε indicates the variability in the response variable (B) which cannot be appropriate to any of the explanatory variables in the equation. β represents the elasticity of change in B (dependent) which is expected to result from a change of one unit in D (independent) when all other independent variables are held constant. e is an analytical function (exponential).

Therefore, the decision was made to test the foregoing relationships using multiple regression analysis as in Schroeder et al. (1981) namely, before transforming data, followed by testing these relationships using ACE technique (models after variable transformation) as in Sum et al. (1995), then checking the statistical significance of comparing between the best linear models and the best ACE's models by evaluating modelling capability of the type of models using adjusted R^2 and P-values, then finally selecting the final models for MRP benefits.

2.2. Evaluating an ACE's model capability

The need to evaluate the capability of ACE's modelling is required before selecting the final models for MRP benefits. To do that, we followed Schroeder *et al*. (1981) and Sum *et al*. (1995). We identified the best linear models by running all possible regression analysis models and selecting the top few models with highest adjusted multiple correlation of the response with the predictors, R^2. The results indicate that the highest adjusted R^2 s extracted by running regression analysis were 0.28 and 0.44[1] in cases of the relationships between delivery lead time benefit and all independent variables and between operational efficiency benefit with all independent variables respectively. Then we ran ACE using the same variables determined in the best linear models. By running ACE using the same variables identified in the best linear models (i.e. models without transformations), the ACE models improved the adjusted R^2 as much as 0.63 (0.91-0.28) and 0.42 (0.86-0.44) percentage points respectively. These results confirm the superior modelling capability of ACE technique.

2.3. Selecting the final models for MRP benefits

Ten final ACE models were selected by running the previous strategies consequently as depicted in Table 5. The parameter's coefficients for determinant variables in the ACE models and small p-values in Table 5 indicate that all ACE models and all determinant variables are very significant. It is interesting to note that all parameters coefficients for the determinant variables (independent) are positive because we regressed the transformed benefit measure (dependent variable) on all the transformed determinant variables (independent) as in Sum *et al*. (1995). Surprisingly, the adjusted R^2 s and P-values are better than Cooper and Zmud (1989; 1990) and Sum *et al*. (1995). For analytical purposes, we used a Dummy variable coding to recode Manufacturing Process and Marketing Strategy into a number of dichotomous variables showing the presence or absence of each category. The first was coded 0 for continuous (includes continuous production and assembly line) and 1 for intermittent (includes batch operation and job shop), the second was coded 0 for make to stock and 1 for make to order (in relation to intermediate levels for marketing strategy making to order and making to stock are presented by fractional numbers).

[1] These results were extracted by using OLS technique in order to get R^2 for the two dependent variables (as examples) with all the forty independent variables before transformations.

Table 5

The ACE models for MRP benefits

Determinant Variable	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	B_9	B_{10}
Uncertainty										
The required products[a]										
Capacity[a]		.0026			.0351					
Reliability			.0045							
*Org. & Tech. & Hum.**										
Source of MRP system**										
Manufacturing process										
continuous		.0088								
intermittent		.0136								
Layout										
Manufacturing strategy										
Make to order	.0525[b]									.0001
Make to stock	.0741									.0651
User involvement										
Utilizing MRP outputs										
Levels in BOM	.0007			.0001	.0005					.2e-4
Company maturity										
User support										
Company size[a]					.0884	.5e-4				
Stage of development[a]				.3e-5	.0003	.0049				
Years in implementation								.0035		
MRP system features										
Education and training										
Experience[a]									.0036	
Vendor support availability[a]	.0048									
Active vendor proficiency[a]										
Vendor experience[a]										
Organizational willingness										
Implementational										
Year in implementation										
Data accuracy										
Supply planning data[a]		.0001						.0013		
Demand planning data[a]							.0003	.0534		
Schedule execution data[a]			.0019							
Operating execution data[a]						.1e-4				
Implementatinal problems										
Technical[a]									.3e-4	
Management support[a]				.0250			.2e-4			
MRP expertise[a]										
People support[a]			.0034				.0002			
Vendor involvement[a]										
Implementation strategy										
Initiator of MRP effort										
Model *p*-value	.1e-6	.7e-5	.1e-3	.4e-9	.2e-5	.1e-5	.1e-6	.4e-5	.2e-6	.1e-6
Model adjusted R^2	0.51	0.43	0.35	0.74	0.45	0.47	0.50	0.39	0.47	0.55
Model R^2	0.56	0.48	0.41	0.78	0.50	0.52	0.53	0.43	0.50	0.61
N	52	52	52	52	52	52	52	52	52	52

[a] Constructed factor. [b] Parameter p-value. All parameter coefficients are positive.

$\mathbf{B_1}$ refers to inventory turnover, $\mathbf{B_2}$ refers to delivery lead time, $\mathbf{B_3}$ refers to percent of time meeting delivery promises, $\mathbf{B_4}$ refers to split orders, $\mathbf{B_5}$ refers to number of expediters, $\mathbf{B_6}$ refers to operational coefficient, $\mathbf{B_7}$ refers to co-ordination, $\mathbf{B_8}$ refers to manufacturing planning and control, $\mathbf{B_9}$ refers to formal system, $\mathbf{B_{10}}$ refers to inventory costs.

* Organizational & Technological & Human. ** Blanks in the table indicate parameter coefficients are not statistically significant (determinant variables not included in the models extracted by ACE technique).

Results

The interpretation of ACE models for MRP benefits

It is interesting to note that the transformed scores of the determinant variables in Table 5 are positively correlated with their corresponding observed benefit scores. This is because all the transformations for the benefit variables are increasing functions whereas all parameters coefficients for the determinant variables are positive as depicted in Table 5. Therefore, we will interpret the parameters coefficients of the independent variables (determinant variables) in order to explore and examine their effects on the dependent variables (MRP benefits) as in Schroeder *et al*. (1981) and Sum *et al*. (1995).

1. Inventory Turnover

As shown in Table 5 the inventory turnover benefit measure is affected by manufacturing strategy, levels in BOM and vendor support availability. The results of the inventory turnover model are statistically significant, with 51.0% of the variance in inventory turnover accounted for (i.e. that manufacturing strategy, levels in BOM and vendor support availability variables had explained approximately 51.0% of changes of inventory turnover benefit measure among the Egyptian users).

Manufacturing strategy

The difference in the parameter estimates between make to order and make to stock variables (see Table 5) is .0216 in favour of make to order strategy, suggesting that more inventory turnover is obtained in make to order than in make to stock environments. Logically, make to stock companies should operate with safety stocks of the end item for protection from stock out until components become available if the company happens to get off schedule, while make to order companies would not be able to have safety stocks of components because they do not know what end items they will be producing and when. As usual, make to order companies are achieving higher inventory turnover (the ratio of sales to the average of inventory level measured at the cost or retailed price) than make to stock companies (Dilworth, 1993). Our results concurs with Schroeder *et al*. (1981) and Sum *et al*. (1995) findings that inventory turnover is significantly better in make to order environments.

Levels in BOM

The p-value of levels in BOM transformation in Table 5 indicates that an increasing level in bill of materials has a positive impact on inventory turnover. The interpretation for the previous result may be related to the fact that more levels in the BOM mean more subassemblies, more intermediates, more parts and more raw materials (Browne et al., 1996), namely more inventory investment and which may lead to high inventory turnover. This finding does not support Schroeder *et al*. (1981) and Sum *et al*. (1995) findings that the complexity product structure which includes parts & components and levels in BOM has an opposite effect on inventory turnover.

Vendor support availability

The p-value of the independent variable, vendor support availability, suggests that as the vendor support increases, the inventory turnover would increase. The explanation of this result is likely to be related to the fact that as a manufacturing company is a beginner in MRP implementation, it expects high support from MRP vendors to overcome the implementation problems and which may be reflected in increasing its performance such as increasing inventory turnover.

2. Delivery Lead Time

Table 5 shows that capacity constraints uncertainty, manufacturing process and supply planning data accuracy are important determinant variables of delivery lead time. The ACE model of delivery lead time indicates that the previous factors are statistically significant and explained approximately 43.0% of the change in delivery lead time among the Egyptian MRP users.

The uncertainty of the capacity

The parameter coefficient in Table 5 suggests that the certainty of the capacity leads to the higher delivery lead times. This can be explained as follows: When the capacity constraints and machine downtime are predictable, the company's ability to use an MRP system to cut delivery lead times is decreased. This may be because the uncertainty of the capacity may lead to the nervousness in the Master Production Schedule, i.e. the MPSs are not held firm by MRP companies, in turn the production can not to meet delivery dates.

Manufacturing process

In contrast to Schroeder *et al*. (1981) and Sum *et al*. (1995) findings that manufacturing processes do not affect the performance measures, our findings suggest that the continuous industries had lower delivery lead times than the intermittent industries because the nature of this industry helps manufacturing companies to make the customer lead time from order to delivery very low. The investigation of the difference in the parameter estimates between continuous and intermittent industries variables (Table 5) is .0048 in support of the continuous industry.

Supply planning data

The parameter coefficient in Table 5 shows that the increase of supply data planning led to an increase in delivery lead time. Our insight into this is built upon the fact that the data extracted from the system become accurate when users accept to follow the recommendations produced by the system anymore (Sum *et al*., 1995). Subsequently any decision or process built upon these data such as determining delivery lead time is proper.

3. Percent of Time Meeting Delivery Promises

The company's ability to meet delivery promises is affected by the degree of uncertainty of the reliability, schedule execution data and people support problems (see Table 5).

The uncertainty of the reliability

Reliability is a constructed factor comprising behaviour of people and reliability of plant within the factory whereas its p-value in Table 5 suggests that manufacturing companies with more reliable behaviour of people and plant within the factory wall had higher percent of time meeting delivery promises. This result concurs with the notion that in order to achieve the successful implementation (the higher performance) the company must integrate the system with daily operations (Duchessi *et al.,* 1989) and which, often, are based on work force planning and master production scheduling.

Schedule execution data

As mentioned in Dilworth (1993) & Browne *et al*. (1996), data accuracy has a positive effect on MRP implementation. The parameter coefficient in Table 5 shows that schedule execution data accuracy has a positive impact on meeting delivery promises. This could be explained by the realistic master schedule as a result of data accuracy usage. This result supports Schroeder *et al*. (1981) and Sum *et al*. (1995) findings that data accuracy affects delivery promises.

People support problem

The p-value supports the notion that higher performance such as higher meeting delivery promises is accompanied by higher people support (Turnipseed *et al*., 1992; Dilworth, 1993). This result concurs with Schroeder et al.'s (Schroeder *et al*., 1981) finding that delivery promises are affected by people support.

4. Percent of Split Orders

Table 5 shows that three independent variables have a significant impact on the percent of spilt orders, they are levels in BOM, stage of development and management support problem respectively.

Levels in BOM

The parameter coefficient of the levels in BOM transformation indicates that increasing levels in bill of materials has a positive impact on the percent of spilt orders. The explanation can be offered for that effect is derived from the fact that a complex BOM is a potential source of inefficiency for a production planning and control system (Sum *et al*., 1995). This may be reflected in increasing the percent of split orders because of unavailable material as was demonstrated by Schroeder *et al*. (1981).

Stage of development

As shown in Table 5 there is a positive relationship between the stage of MRP implementation and the percent of split orders. As the stage of MRP implementation increases, the percent of split orders increases because of available material. This concurs with the notion that when companies adopt an advanced stage of MRP system (i.e. Classes B & A) the accuracy and stability of master production schedule will increase. As a consequence, the degree of accuracy of BOM also will be increased. This result does not support Schroeder *et al*. (1981) and Sum *et al*. (1995) findings that the percent of split orders is adversely affected by the stage of MRP implementation.

Management support problem

The parameter coefficient in Table 5 supports the notion that higher performance is accompanied by higher top management support. This result affirms the importance of top management support for improving the operational use and improving performance (Duchessi *et al*., 1989) and also, conforms with the findings of Schroeder *et al*. (1981) and Sum *et al*. (1995).

5. Number of Expediters

The ACE model for number of expediters (Table 5) indicates that the levels in BOM, company size and stage of MRP implementation variables had explained approximately 45.0% of changes of the number of expediters among the Egyptian users.

Levels in BOM

The p-value suggests that as the levels of bill of materials increase the number of expediters is likely to be increased. This is expected because increasing levels in BOM may lead to an increase in materials, subassemblies, and parts behind schedule. This means that a company may need to increase the number of expediters in order to meet customers needs in the due dates.

Company size

The parameter coefficient suggests that increasing company size has a positive impact on the number of expediters. Since company size is related to the scale and scope of the manufacturing operations (Sum *et al*., 1995), therefore the large companies are likely to have more hot jobs and more behind schedule, which may lead to the need to more expediters in order to reduce the deviations between two dates (due date and need date), namely making the two dates coincided (Plossl, 1995). This supports the findings of Schroeder *et al*. (1981) and Sum *et al*. (1995).

Stage of development

Table 5 affirms the importance of the stage of development in increasing performance. The p-value suggests that as the stage of development increases, the growing computerisation in all MRP modules such as inventory control, bill of materials and master production schedule increases, and this will be reflected in minimising behind schedule, namely, minimising the number of expediters. This result supports Schroeder *et al*. (1981) and Sum *et al*. (1995) findings that the number of expediters is adversely affected by the stage of MRP implementation.

6. Operational Efficiency

Table 5 shows that operational efficiency (increased throughput and improved product quality) is affected by company size, the stage of development and operating execution data accuracy.

Company size

The parameter coefficient of the size transformation indicates that increasing company size has a positive impact on inefficiency. This can be explained in the light of the fact that as size gets too big, the conflicting technologies, objectives, processes, and procedures might set in (Sum *et al*., 1995). Consequently, further benefits have not been reaped, in turn companies try to keep on the existing level of benefits achieved. This is consistent with Sum et al.'s (Sum *et al*., 1995) finding that increasing size has a negative impact on efficiency. They stated that as size increases, diseconomies and inefficiencies due to conflicting technologies, objectives, processes and procedures might set in.

Stage of MRP implementation

The parameter coefficient in Table 5 supports the fact that increasing stage of MRP implementation means that company tends to develop the formal system of planning and control by increasing formal policies, procedures and responsibilities (Duchessi *et al*., 1989).

Operating execution data

The p-value of the operating execution data accuracy shows that high data accuracy is needed to achieve both the tangible and subjective benefits. An explanation could be that operational efficiency requires accurate data about planning data (capacity, vendor lead times, production lead times) and execution data (shop floor control). Thus, data accuracy can be considered as a major determinant variable of the successful implementation (Duchessi *et al*., 1989).

7. Co-ordination

The ACE model for co-ordination benefit reveals that demand planning data and management support problem are statistically significant independent variables affecting co-ordination among operations, marketing and finance.

Demand planning data

The parameter coefficient in Table 5 supports the fact that the higher co-ordination among functions and sub-systems within the organisation is accompanied by higher quality of data flow across them (Sum *et al*., 1995).

Management support problem

The p-value suggests that increasing management support has a positive impact on co-ordination. An explanation could be that effective co-ordination requires management support to set clear goals for the implementation and to distribute responsibilities across functional areas (Duchessi *et al*., 1989).

8. Manufacturing Planning and Control

Table 5 shows that two independent variables are statistically significant and explained approximately 50.0% of the change in manufacturing planning and control among the Egyptian users.

Year in implementation

The p-value suggests that increasing years in implementation has a positive impact on manufacturing planning and control. The positive impact of older system on manufacturing planning and control can be explained by user acceptance of the system as a result of prolonged usage (Sum *et al*., 1995).

Supply planning data

The parameter coefficient of supply planning data exhibits a positive impact on manufacturing planning and control. An explanation could be that supply planning data such as capacity data, vendor lead times and production lead times data may allow managers to obtain reports on the material flow, the right parts at the right place at the right time. This may be reflected in the efficiency of MPC system.

9. Formal System

As shown in Table 5 the formal system benefit measure is affected by the degree of experience and technical problems. The results of the formal system model are statistically significant, with 47.0% of the variance in formal system accounted for.

Experience with CAPM

The parameter coefficient in Table 5 suggests that increasing previous experience with CAPM systems has a positive impact on formal systems. This is expected, because increasing experience with automated information systems is likely to increase people's ability to understand and accept any prerequisites for a new formal systems such as the policies which describe how to perform business functions (e.g., forecasting, master production purchasing, cost accounting), procedures which describe how to enter and verify associated system transactions, and the distribution of responsibilities. The acceptance of these formal issues permit using the system, conducting business, and achieving data accuracy (Duchessi *et al*., 1989).

Technical problem

The p-value indicates that as the technical problems increase, the need for formal system increase in order to reduce informal systems for material management/inventory/ production control and to increase BOM/inventory/MPS data accuracy. This result concurs with Sum et al.'s (Sum *et al*., 1995) finding that increasing technical problems requires high co-ordination among departments and sub-systems, and which may demonstrate the need for increasing formal systems to formalise policies, procedures and distribute responsibilities.

10. Inventory Costs

The ACE model of inventory cost benefit (Table 5) shows that inventory cost is affected by type of product and levels in bill of materials.

Manufacturing strategy

The difference in the parameter estimates between make to order and make to stock variables concerning inventory costs benefit (Table 5) is .0650 (.0651 make to stock- .0001 make to order) in favour of make to order, namely make to order is highly statistically significant more than make to stock. This suggests that more reduction in inventory costs is obtained in make to order than make to stock where the last strategy has higher inventory costs (Browne *et al*., 1996).

Levels in BOM

The parameter coefficient in Table 5 supports the notion that higher levels in BOM are accompanied by higher inventory costs. This result concurs with the fact that more levels in bill of materials means more inventory investment (Plossl, 1995).

Summary and conclusions

Having discussed the mathematical results of the relationships between uncertainty, organisational, implementational, technological and human determinant variables and the benefits obtained from MRP implementation, the following is a summary of the main findings:

1. As a whole, the results of ACE model provide us with valuable information which does not support our hypothesis that the benefits obtained from MRP implementation do not correlate with the determinant variables in a linear manner.

2. The level in bills of materials (BOM) appears to be a critical determinant variable in affecting inventory turnover, percent of split orders, number of expediters and inventory costs. This is expected because levels in BOM identify the components parts of a final output product at each level and indicate the complexity of detailed material planning.

3. This study reveals that high data accuracy leads to speed of delivery, increased operational efficiency, and increased coordination among departments within the company. This will be reflected in increasing the user's level of confidence in and acceptance of the system.

4. Our findings reveal that as capacity uncertainty increases delivery lead time and the number of expediters increase in order to meet due dates.

5. Consistent with past literature, manufacturing companies implementing a make to order strategy attained increased inventory turnover more than companies implementing a make to stock strategy.

6. Our findings show that management support and people support are critical to increasing the percent of delivery promises, to improving coordination and to achieving operational efficiency.

7. This study indicates that stage of the MRP implementation can have a positive impact on both percent of split orders and number of expediters.

8. Our findings indicate that company size can have a positive impact on operational efficiency. This may be because big companies may have the capability to successfully operate MRP systems in terms of having experts in automated information systems and increasing investment in advanced systems, etc.

Managerial Implications

The study findings appear to have theoretical and practical implications for both MRP managers and users in Egyptian manufacturing companies and for researchers. Therefore, the following theoretical and practical implications can be drawn:

(1) As the empirical results indicate that data accuracy appears to be critical in affecting the benefits obtained from MRP implementation, managers and users must devote more efforts to maintain data accuracy at a high level if they want to obtain significant benefits from their MRP systems.

(2) The linear relationships between uncertain capacity and the benefits obtained from MRP implementation suggest that MRP managers must expend extra effort to estimate the right capacity (usually in hours) of each machine or work centre in order to maintain the efficiency of their production planning and control system.

(3) Our empirical results indicate that as company size increases the need for more expediters increases, also as size gets too big the operational efficiency increases. This is a good sign for decision makers in small size companies who are hesitating to adopt MRP system due to size considerations indicating that they might be able to implement and operate MRP systems effectively.

(4) A very significant implication is that the stage of MRP implementation was found to be crucial to the benefits obtained from MRP implementation. This suggests that management commitment must be extended for implementing an advanced stage of MRP system if they want to realise more benefits from their MRP system.

(5) Our findings suggest that there is a positive impact of "people support" on the benefits obtained from MRP implementation. The main implication is that people problems should be monitored very closely by managers and also they have to understand that informal systems should exist and be sustained alongside the formal system if they want to attain significant benefits from their MRP system.

(6) The linear relationship between people support and co-ordination among departments may suggest that top management should pay more intention into monitoring MRP usage among different departments such as production, finance, and marketing departments, if they want to achieve the effectiveness of MRP implementation.

Recommendations for Further Research

Since this study is considered as the first attempt to investigate the state of practice of MRP implementation in less developed countries in general, and in Egypt in particular, directions for further research are suggested:

(1) The recommendation is made for further comparative studies with other less developed countries which could find out the similarities and dissimilarities concerning MRP implementation.

(2) Case studies need to be conducted to present more details concerning MRP implementation processes.

(3) Investigation is needed about MRP implementation in the private sector in comparison with the public sector.

(4) The major findings of this research indicate that the critical factors affecting the successful implementation of MRP systems within manufacturing companies are varied and interrelated together. This implies that an in-depth analysis of each factor or each group of factors at the most is required.

(5) As the current study has been considered the second attempt to explore and examine the MRP benefit-determinant relationships using the Alternating Conditional Expectations (ACE), future studies could be conducted to validate the findings presented in this study.

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