An exploratory study of MRP benefit–determinant relationships: ACE analysis model

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Abstract: This paper aims to examine the MRP (MRPI and 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 and 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 the ACE technique as an advanced statistical modelling technique. The data analysed in this paper were collected by a mail questionnaire sent to Egyptian manufacturing firms. The findings indicate that data accuracy has a positive effect on the successful implementation of MRP systems. Also, our findings indicate that, as capacity uncertainty increases, so delivery lead time and the number of expediters increase in order to meet due dates. Moreover, our findings show that a company's size has a positive impact on operational efficiency. Managerial implications and avenues for further research are recommended.

Keywords: ACE; benefits; human variables; implementation; manufacturing; MRP; organisational; technological; uncertainty.

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1 Introduction

It has often been said that the strength of any country resides in the strength of its industrial sector. In this respect, Egypt of the 21st century has multiplied its strength ten-fold and 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
- losing market share
- high levels of inventory
- poor quality in products and labour
- long lead times
- the existence of many sources of waste in production processes (Salaheldin and Francis, 1998; Salaheldin, 2004, 2005).

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 researchers' 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 Braglia and Petroni (1999), Petroni (2002), Petroni and Rizzi (2001), Salaheldin and Francis (1998), Sum and Yang (1993), Sum et al. (1995) and Towers et al. (2005), reported in their studies that there is a lack of empirical studies concerning the MRP benefit–determinant relationships in the Western manufacturing firms, the newly industrialised countries or in less developed countries (LDC's) in general and in Egypt in particular. Therefore, the researchers have found it feasible to conduct this study.

2 Importance of the study

This study will add more empirical findings to the operations management literature 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, the researchers' 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).

3 Study objectives

In the light of the importance of the study, there are three objectives of the current study. They are as follows:

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 examine the MRP benefit-determinant relationships.

4 Related research

An extensive review of the literature reveals that MRP benefits have been measured in three ways. Firstly, studies such as Aghazadeh (2003), Anderson and Schroeder (1984), Anderson et al. (1982), Cerveny and Scott (1989), Laforge and Sturr (1986) and Petroni and Rizzi (2001) have measured MRP benefits by actual use or improved performance measures. These are:

- increasing inventory turnover
- better delivery lead time
- increasing percentage of time meeting delivery promises
- reducing percentage of order requiring 'splits' because of unavailable material
- reducing number of expediters.

However, there is a difficulty in obtaining measures of actual use (White et al., 1982), because companies often cannot keep track of the performance measures over time (Raymond and St-Pierre, 2005; 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 Du et al. (2005), Duchessi et al. (1988), Sum and Yang (1993) and Sum et al. (1995). They have measured MRP benefits by attitudes, intentions or behaviour 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
- improved morale in production.

Thirdly, studies such as White et al. (1982) and Schroeder et al. (1981) have measured benefits by both improved performance and subjective benefits.

On the other hand, several researchers and practitioners have indicated that there are five groups of factors affecting the successful implementation of MRP systems. Firstly, MRP implementation is affected by the degree of uncertainty and 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 (Dilworth, 1993; Gerwin and Kolodny, 1992; Per-lind, 1991; Prater, 2005; Puttick, 1987). Secondly, as pointed out by several writers such as Anderson et al. (1982), Burns and Turnipseed (1991), Duchessi et al. (1988), Koh et al. (2000), Lee (1993), Samaranayake et al. (2002), Sum et al. (1995) and Wermus (2001), the organisational factors, such as:
  - company age
  - company size
  - type of products
  - type of manufacturing
  - layout
  - company complexity
  - organisational arrangements
  - organisational willingness

cannot be seen only as determinants of MRP implementation but also as determinants of MRP benefits. Thirdly, it is generally believed that MRP implementation is influenced by several implementational factors such as:

- years of implementation
- implementation strategy
- degree of data accuracy
- initiator of MRP effort
- software/hardware vendors support
- implementation problems (Aghazadeh, 2003; Ang et al. 1995; Badiru and Schlegel, 1994; Sum and Yang, 1993; Sum et al. 1995; White, 1980; Wight, 1989; Wong and Kleiner, 2001).

Fourthly, as put forth in numerous studies, such as Browne et al. (1996), Carrie and MacIntosh (1993), Chung and Snyder (2000), Duchessi et al. (1988), Keung et al. (2001), Sum and Yang, (1993) and Vollman et al. (1992), several technological factors (degree of integration among MRP modules, source of system, system cost, additional investment over the next three years, user class and MRP system features) are affecting the implementation of MRP systems. Finally, as pointed out by several writers such as Burns et al. (1991), Callarman and Heyl (1986), Chan et al. (1999), Ip (1998), Sum et al. (1995), Turnipseed et al. (1992), White et al. (1982) and Wight (1984), 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 the 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 summary, a review of the literature and previous empirical studies reveal 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 aforementioned gaps. To do that, a suggested model framework of determinant variables of MRP implementation benefits is depicted in Table 1.

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	Percentage of time meeting delivery promises	N
The standard of raw material (quality)	O	Percentage of orders requiring 'splits' due to 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		
Capacity constraints	O		

Table 1 The framework of determinant variables of MRP implementation benefits (continued)

Determinant variables	*Type**	*MRP implementation benefits*	*Type**
Uncertainty determinants		*Tangible benefits*	
Company age	O	Improved competitive position	O
Company size	O	Reduced inventory costs	O
Type of products	C	Increased throughput	O
Type of manufacturing	C	Improved product quality	O
Layout	C	Improved productivity	O
Company complexity	O	Better ability to meet volume/product change	O
Organisational arrangements	C	Better production scheduling	O
Organisational willingness	C	Reduced safety stocks	O
		Better cost estimation	O
		Improved co-ordination with marketing and finance	O
		Improved your ability to perform in your job	O
		Reduced informal systems for materials management/inventory/production control	O
		Increased BOM/inventory/MPS accuracy	O
		Increased information on which to base decisions since MRP has been implemented	O
Implementational determinants			
Years in implementation	O		
Implementation strategy	C		
Degree of data accuracy	O		
Initiator of MRP effort	C		
Software/hardware vendors support	O		
Implementation problems	O		
Technological determinants			
Degree of integration among MRP modules	D		
Human determinants			
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		

Notes: *O refers to ordinal variable; C refers to categorical variable; D refers to discrete variable; N refers to numerical variable

4 Hypothesis

This empirical research systematically investigated MRP benefit–determinant relationships within manufacturing firms in Egypt. Therefore, it is worthwhile working on the following hypothesis: the uncertainty and organisational, implementational, technological and human variables do not correlate with the benefits obtained from MRP implementation in a linear manner.

5 Study methodology

5.1 The sample

The mail survey, sent to approximately 200 ex-public (holding) manufacturing firms in Egypt, focused on:

- uncertainty determinants
- organisational determinants
- implementational determinants
- technological determinants
- human determinants
- MRP benefits.

Firms of the sample were randomly selected from a list of all manufacturers in the Egyptian ex-public industrial sector.[3] 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 to be good compared with similar studies reported in the literature (Sum and Yang, 1993; Sum et al., 1995).

5.2 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. (1988, 1989), Sum and Yang (1993) and Sum et al. (1995). The modifications made to these studies were determined by the researchers' 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.

5.3 Measurements

5.3.1 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)
- minimise the number of variables which have a high loading on a factor
- 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

	Factors					*Communality*
MRP success measures	*1*	*2*	*3*	*4*	*5*	
Factor 1: operational efficiency						
Increased throughput	0.75					0.60
Improved product quality	0.67					0.49
Factor 2: co-ordination						
Better cost estimation		0.70				0.58
Improved co-ordination with marketing and finance		0.78				0.70
Factor 3: manufacturing planning and control						
Better production scheduling			0.70			0.60
Reduced safety stocks			0.68			0.74
Factor 4: formal system						
Reduced informal systems for materials management/ inventory/production control				0.74		0.69
Increased BOM/inventory /MPS accuracy				0.65		0.58
Factor 5: inventory costs						
Reduced inventory costs					0.79	0.70

Notes: The values underneath each factor are correlation coefficients between the factor and the variables

Communalities mean estimates of the variance in each variable

Table 3 Determinant variables factor loadings

Determinant variables	*Factors* 1	2	3	4	5	6	7	8	*Communality*
Factor 1: the required products									
Product characteristics diversity	0.72								0.64
Amount of aggregate product demand	0.73								0.62
The standard of raw material	0.71								0.53
Factor 2: capacity									
Machine downtime		0.65							0.56
Capacity constraints		0.80							0.68
Factor 3: reliability									
Behaviour of people within the factory			0.70						0.57
Reliability of plant within the factory			0.74						0.68
Factor 4: technical									
Lack of suitability of hardware				0.82					0.72
Lack of suitability of software				0.63					0.53
Poor training/education on MRP				0.77					0.73
Factor 5: management support									
A lack of support from top management					0.75				0.73
Lack of support from production					0.78				0.68
Lack of support from marketing					0.63				0.65
Factor 6: MRP expertise									
Lack of communication						0.73			0.60
Lack of information technology expertise						0.75			0.77
Factor 7: people support									
Lack of support from supervisor/foreman							0.76		0.69
Lack of company expertise in MRP							0.66		0.67

Table 3 Determinant variables factor loadings (continued)

	Factors								Communality
Determinant variables	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	
Factor 8: active vendor involvement									
Lack of involvement from vendor							0.77		0.71
Determinant variables	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	
Factor 9: size									
Sales	0.62								0.52
Number of P & I C employees	0.85								0.81
Number of items per product	0.69								0.63
Factor 10: stage of development									
User class[4]		0.65							0.54
Degree of integration		0.70							0.57
Factor 11: experience									
Previous experience with automated information systems			0.84						0.73
Factor 12: BOM level									
Number of BOM levels				0.75					0.63
Factor 13: company maturity									
Years in operation					0.75				0.61
Factor 14: vendor support availability									
We expected more extensive vendor support						0.76			0.68
We experienced a vendor software support discontinuance problem						0.73			0.63
Factor 15: active vendor proficiency									
Vendor instructions interpret their software product							0.77		0.74
Vendor personnel efficiently resolved software problems							0.90		0.84
Factor 16: vendor experience									
The vendor provided conversion of our data into the new system								0.93	0.88

Table 3 Determinant variables factor loadings (continued)

	Factors				*Communality*
Determinant variables	*17*	*18*	*19*	*20*	
Factor 17: supply planning data					
Capacity data	0.79				0.64
Vendor lead times	0.76			0.61	
Production lead times	0.63			0.50	
Factor 18: demand planning data					
Bill of material records		0.69			0.58
Inventory records		0.68			0.76
Market forecasts		0.75			0.77
Factor 19: schedule execution data					
Master production schedule			0.87		0.79
Routing/work centre data			0.63		0.56
Factor 20: operating execution data					
Shop floor control data				0.84	0.74

From Tables 2 and 3, we notice that five out of 14 subjective benefits measures are extracted. In addition, 20 out of 40 uncertainty and organisational, implementational, technological and human determinant variables are extracted. In turn, regression models will be developed for each benefit separately using the ACE technique as discussed in the next section.

5.3.2 *Testing the hypothesis using the 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 predictor (independent) variables that maximise the multiple correlation, R^2, to achieve increased linear associations between Y (dependent) and set $X_1 \ldots, X_n$ (independent). Furthermore, the ACE model has a much better model fit compared with 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.

5.3.2.1 To decide whether transformation is necessary

One of the common methods used for determining whether or not a transformation is necessary is skewness. If the original data are 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 candidates to be transformed and vice versa. Equation (1) shows the significance of skewness:

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

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.

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

Table 4 Statistics to depict the significance of skewness

Variables	*Skewness*	*S.E. skew*	*The significance of skewed data*
Vendor experience	1.24	0.33	3.76
Co-ordination	-0.60	0.33	-1.82
Active vendor proficiency	2.94	0.33	8.91
Inventory costs	-0.58	0.33	-1.76
Vendor support availability	1.45	0.33	4.39
Organisational willingness	0.13	0.33	0.39
Manufacturing P&C	-0.73	0.33	-2.21
Supply planning data	0.68	0.33	2.06
Demand planning data	0.59	0.33	1.79
Company size	0.82	0.33	2.48
Levels in BOM	0.31	0.33	0.94
Company maturity	-2.60	0.33	-7.88
Stage of development	0.19	0.33	0.58
Formal system	0.04	0.33	0.12
Technical problems	-1.08	0.33	-3.27
Schedule execution data	0.11	0.33	0.33
Uncertain capacity	0.87	0.33	2.64
Uncertain required products	0.10	0.33	0.30
Management support problems	-1.44	0.33	-4.36

Table 4 Statistics to depict the significance of skewness (continued)

Variables	*Skewness*	*S.E. skew*	*The significance of skewed data*
Active vendor involvement	0.02	0.33	0.06
Layout	0.28	0.33	0.85
Uncertain reliability	0.35	0.33	1.06
People support problems	0.74	0.33	2.24
Operational efficiency	0.28	0.33	0.85
MRP expertise problem	0.25	0.33	0.76
Experience with automated systems	-0.25	0.33	-0.76
Operating execution data	1.83	0.33	5.55
Organisational arrangements	0.96	0.33	2.91
Initiator of MRP effort	2.86	0.33	8.67
Implementation strategy	0.91	0.33	2.76
Meeting delivery promises	0.30	0.33	0.91
Marketing strategy	0.08	0.33	0.24
The number of expediters	-84.00	0.33	-2.43
The percentage of split orders	-0.14	0.33	-0.42
Source of system	0.25	0.33	0.76
Inventory turnover	-0.33	0.33	-1.00
Delivery lead times	0.25	0.33	0.76
Utilising outputs	1.33	0.33	4.03
User involvement	0.11	0.33	0.33
Manufacturing process	1.25	0.33	3.79
Years in implementation	0.13	0.33	0.39
MRP system features	0.91	0.33	2.67
User support	0.30	0.33	0.91
Education and training	0.25	0.33	0.76

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, it has been concluded that the data of some of the variables under investigation can be described in a linear manner and the others have a 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 the 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). Therefore, a regression model is non-linear as shown in Equation (2) below:

$$B = \alpha + e^{\beta_1 D} + \varepsilon \qquad (2)$$

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 appropriated 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, by testing these relationships using the 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 models by evaluating the modelling capability of the type of models using adjusted R^2 and p-values then, finally, selecting the final models for MRP benefits.

5.3.2.2 Evaluating an ACE model's capability

The need to evaluate the capability of ACE's modelling is required before selecting the final models for MRP benefits. To do that, the researchers Schroeder et al. (1981) and Sum et al. (1995) identified the best linear models by running all possible regression analysis models and selecting the top few models with the highest adjusted multiple correlation of the response with the predictors, R^2. The results indicate that the highest adjusted R^2 extracted by running regression analyses were 0.28 and 0.44[5] in the cases of the relationships between delivery lead time benefit and all the independent variables and between the operational efficiency benefit with all independent variables respectively. Then ACE is run 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 the ACE technique.

5.3.2.3 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 parameter coefficients for the determinant variables (independent) are positive because the researchers 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 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 to stock are presented by fractional numbers).

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]		0.0026			0.0351					
Reliability			0.0045							
*Org. & Tech. & Hum.**										
Source of MRP system**										
Manufacturing process										
• Continuous		0.0088								
• Intermittent		0.0136								
Layout										
Manufacturing strategy										
• Make to order	0.0525[b]									0.0001
• Make to stock	0.0741									0.0651
User involvement										
Utilising MRP outputs										
Levels in BOM	0.0007			0.0001	0.0005					0.2e-4
Company maturity										
User support										
Company size[a]					0.0884	0.5e-4				
Stage of development[a]				0.3e-5	0.0003	0.0049				
Years in implementation								0.0035		
MRP system features										
Education and training										
Experience[a]									0.0036	
Vendor support availability[a]	0.0048									
Active vendor										
Vendor experience[a]										
Organisational willingness										
Implementational										
Year in implementation										
Data accuracy										
• Supply planning data[a]		0.0001						0.0013		
• Demand planning data[a]							0.0003	0.0534		

Table 5 The ACE models for MRP benefits (continued)

Determinant variable	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	B_9	B_{10}
• Schedule execution data[a]			0.0019							
• Operating execution data[a]							0.1e-4			
Implementational problems										
• Technical[a]									0.3e-4	
• Management support[a]				0.0250			0.2e-4			
• MRP expertise[a]										
• People support[a]			0.0034				0.0002			
• Vendor involvement[a]										
Implementation strategy										
Initiator of MRP effort										
Model *p*-value	0.1e-6	0.7e-5	0.1e-3	0.4e-9	0.2e-5	0.1e-5	0.1e-6	0.4e-5	0.2e-6	0.1e-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

Notes: [a]constructed factor, [b]parameter p-value. All parameter coefficients are positive

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

*Organisational and technological and human. **Blanks in the table indicate parameter coefficients are not statistically significant (determinant variables are not included in the models extracted by the ACE technique)

6 Results

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 parameter 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).

6.1 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).

6.1.1 *Manufacturing strategy*

The difference in the parameter estimates between make to order and make to stock variables (Table 5) is 0.0216 in favour of a make to order strategy, suggesting that a higher inventory turnover is obtained in make to order than 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 retail price) than make to stock companies (Dilworth, 1993). Our results concur with the findings of Schroeder et al. (1981) and Sum et al. (1995), that inventory turnover is significantly better in make to order environments.

6.1.2 *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 means more subassemblies, more intermediates, more parts and more raw materials (Browne et al., 1996 and Du et al., 2005), namely more inventory investment which may lead to high inventory turnover. This finding does not support the findings of Bragg et al. (2005), Schroeder et al. (1981) and Sum et al. (1995), that the complexity product structure which includes parts and components and levels in BOM has an opposite effect on inventory turnover.

6.1.3 *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, when a manufacturing company is a beginner in MRP implementation it expects high support from MRP vendors to overcome the implementation problems which may be reflected in increasing its performance, such as increasing inventory turnover.

6.2 *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 represent approximately 43.0% of the change in delivery lead time among the Egyptian MRP users.

6.2.1 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 decreases. This may be because the uncertainty of the capacity may lead to the instability in the master production schedule, i.e. the MPS is not held firm by MRP companies, in turn the production can not meet delivery dates.

6.2.2 Manufacturing process

In contrast with the findings of Schroeder et al. (1981) and Sum et al. (1995), that manufacturing processes do not affect the performance measures, the findings of this study 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 0.0048 in support of the continuous industry.

6.2.3 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 the recommendations produced by the system (Sum et al., 1995). Subsequently, any decision or process built upon these data, such as determining delivery lead time, is proper.

6.3 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 (Table 5).

6.3.1 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 spent higher percentage of time meeting delivery promises. This result concurs with the idea that, in order to achieve the successful implementation (the higher performance), the company must integrate the system with daily operations (Duchessi et al., 1989).

6.3.2 Schedule execution data

As mentioned in Browne et al. (1996) and Dilworth (1993), 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 the findings of Schroeder et al. (1981) and Sum et al.'s (1995), that data accuracy affects delivery promises.

6.3.3 People support problem

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

6.4 Percentage of split orders

Table 5 shows that three independent variables have a significant impact on the percentage of split orders, they are:

- levels in BOM
- stage of development
- management support problem.

6.4.1 Levels in BOM

The parameter coefficient of the levels in BOM transformation indicates that increasing levels in bill of materials have a positive impact on the percentage of split orders. The explanation which 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 percentage of split orders because of unavailable material, as demonstrated by (Schroeder et al., 1981).

6.4.2 Stage of development

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

6.4.3 Management support problem

The parameter coefficient in Table 5 supports the idea 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 to the findings of Schroeder et al. (1981) and Sum et al. (1995).

6.5 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.

6.5.1 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.

6.5.2 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), the large companies are likely to have more hot jobs and more behind schedule, which may lead to the need for more expediters in order to reduce the deviations between two dates (due date and needed date), namely making the two dates coincide (Plossl, 1995). This supports the findings of Schroeder et al. (1981) and Sum et al. (1995).

6.5.3 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 the findings of Schroeder et al. (1981) and Sum et al. (1995), that the number of expediters is adversely affected by the stage of MRP implementation.

6.6 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.

6.6.1 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, 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 the findings of Sum et al. (1995), 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.

6.6.2 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).

6.6.3 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 on planning (capacity, vendor lead times, production lead times) and execution (shop floor control). Thus, data accuracy can be considered as a major determinant variable of the successful implementation (Duchessi et al., 1989).

6.7 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.

6.7.1 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).

6.7.2 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).

6.8 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.

6.8.1 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 systems on manufacturing planning and control can be explained by user acceptance of the system as a result of prolonged usage (Sum et al., 1995).

6.8.2 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, 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.

6.9 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.

6.9.1 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 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 permits using the system, conducting business and achieving data accuracy (Duchessi et al., 1989).

6.9.2 Technical problem

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

6.10 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.

6.10.1 Manufacturing strategy

The difference in the parameter estimates between make to order and make to stock variables concerning inventory costs benefit (Table 5) is 0.0650 (0.0651 make to stock, 0.0001 make to order) in favour of make to order, namely make to order is more highly statistically significant 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).

6.10.2 Levels in BOM

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

7 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.

As a whole, the results of the 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.

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

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

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

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.

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

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

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

8 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.

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 effort to maintaining data accuracy at a high level if they want to obtain significant benefits from their MRP systems.

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.

Our empirical results indicates 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 hesitatant to adopt an MRP system due to size considerations, indicating that they might be able to implement and operate an MRP system effectively.

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 to implementing an advanced stage of MRP system if they want to realise more benefits from their MRP system.

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.

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

9 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.

The recommendation is made for further comparative studies with other less developed countries, which could find out the similarities and dissimilarities concerning MRP implementation. Also, case studies need to be conducted to present more details concerning MRP implementation processes. Moreover, an investigation is needed about MRP implementation in the private sector in comparison with the public sector.

As the current study is considered to be the second attempt to explore and examine the MRP benefit–determinant relationships using alternating conditional expectations (ACE), future studies could be conducted to validate the findings presented in this study.

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Notes

[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 eight general managers and 13 production managers in Egyptian manufacturing firms.

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

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

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